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Musham, Harry A.

Newberry, Truman H.
Niblack, Albert P.
Nickerson, H. O.

Olcott, Alfred V. S.
Osborn, Frank H.

Page, Newman.
Paine, Cecil E.
Peck, Claude J.
Pender, Benjamin D.
Phillips, William H.
Piek, William F., Jr.
Pleasants, William H.
Powelson, Wilfred V. N.

Raven, Anton A.
Raymond, Harry H.
Raymond, James R.
Rea, Samuel.
Reuterdahl, Henry.
Richardson, Eugene M.
Richardson, Holden C.
Robins, William B.
Rodgers, William L.
Rogers, Walter H.
Rossell, Henry E.
Ruprecht, Fritz K.
Russel, John R.
Russell, John E.

Sabin, Alvah H.
Sanford, Leigh R.
Satterlee, Herbert L.
Schafer, Charles A.
Scholz, Robert C.
Sebree, Uriel.
Shaw, Howard L.
Shaw, William.
Simpson, Robert C.
Sitt, William T.
Smith, Alfred G.
Smith, Bryant R.
Smith, Robert A. C.
Smith, William A. F.
Speakman, Edward M.
Sprague, Frank J.

Taylor, Stevenson Peirce.
Thomas, Joseph D.
Thorp, Harry W.
Toch, Henry M.
Todt, Edward G.
Truscott, Starr.

Van Duzer, Louis S.
Veit, Richard C.

Wales, Charles M.
Walker, Herbert B.
Welles, Roger, Jr.
White, George A.
Whiton, Chauncey G.
Wilkinson, Horace S.
Williams, Ralph D.
Williams, William E.
Winslow, John.
Wood, Henry A. Wise.
Wright, William L.

JUNIORS

Adams, Henry C., Jr.
Allen, Walter D.
Altamiranos, Felipe.

Baier, Louis A.

Colby, Haldwell S.
Colley, G. A.

Jennison, Clay L.

Laing, George, Jr.
Lingan, Prentiss.

Newton, G. A.

Peterson, Carl E.

Rakestraw, Linn M.
Roundry, Caryl H.

Schmidt, John D.
Smith, Ralph M.

Thearle, Philip H.
Track, Frank A.
Todd, J. Herbert.

Yuan, Tsin.

ARTICLES OF INCORPORATION

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

STATE OF NEW YORK,
CITY AND COUNTY OF NEW YORK.

We, the subscribers, WM. H. WEBB, CHAS. H. CRAMP, GEORGE E. WEED, H. TAYLOR GAUSE, WILLIAM T. SAMPSON, HORACE SEE, FRANK L. FERNALD, FRANCIS T. BOWLES, WASHINGTON L. CAPPS, EDWIN D. MORGAN, GEORGE W. QUINTARD, HARRINGTON PUTNAM and JACOB W. MILLER, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under, and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific, and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

First. The name of title by which the Society shall be known in law is THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

Second. The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

Third. The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

Fourth. The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

Fifth. The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

IN WITNESS WHEREOF we have made, signed and acknowledged this Certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.
FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

CITY AND COUNTY OF NEW YORK, *ss:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

JAMES FORRESTER,
Notary Public, Kings Co., Cert. N. Y. Co.

CITY AND COUNTY OF NEW YORK, *ss:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

JAMES FORRESTER,
Notary Public, Kings Co., Cert. N. Y. Co.

CITY AND COUNTY OF NEW YORK, *ss:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

JAMES FORRESTER,
Notary Public, Kings Co., Cert. N. Y. Co.

(ENDORSED.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within Certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

EDWD. PATTERSON,
Justice of the Supreme Court in the State of New York,
in and for the City and County of New York.

CONSTITUTION AND BY-LAWS OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

ARTICLE I.

Name and Object.

1. The name of the Association shall be "THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS."

2. Its object shall be the promotion of the art of shipbuilding, commercial and naval.

3. In furtherance of this object, annual meetings shall be held for the reading and discussion of appropriate papers and interchange of professional ideas, thus making it possible to combine the results of experience and research on the part of shipbuilders, marine engineers, naval officers, yachtsmen, and those skilled in producing the material from which ships are built and equipped.

ARTICLE II.

Membership.

1. The Society shall consist of Members, Associates, Juniors, Honorary Members and Honorary Associates.

2. *Members.*—(1) The class of Members shall consist exclusively of Naval Architects, Marine and Mechanical Engineers, including Professors of Naval Architecture or Mechanical Engineering in colleges of established reputation.

(2) A candidate for this class must not be less than twenty-eight years of age and comply with the following regulations: He shall submit to the Council a statement showing that he has been engaged in the practice of his profession, in a responsible capacity, for at least five years, and setting forth the grounds upon which he bases his claim to membership. This statement shall be signed by three Members, who shall certify to their personal knowledge of the candidate and approval of his statement.

(3) In the case of persons not American citizens, the signatures of three Members shall be required in confirmation of their personal knowledge of the candidate's scientific attainments.

(4) If three-fourths of the members of the Council present are in favor of the admission of the candidate his name shall be submitted to the Members of the Society at the next meeting; the voting to be by ballot, should a ballot be demanded.

3. *Associates.*—(1) The class of Associates shall consist of persons who, by profession, occupation, or scientific attainments, are qualified to discuss the qualities of a ship.

(2) Candidates for this class shall submit to the Council a written statement of their qualifications for membership; this shall be signed by two Members or Associates who shall certify to their personal knowledge of the candidate and approval of his statement. If considered by three-fourths of the Council present duly qualified for associate membership their

names shall be submitted to the Society at the next meeting, to be voted upon by the Members and Associates; the voting to be by ballot, should a ballot be demanded.

4. The proportion of favorable votes for deciding the election of Members and Associates shall be at least four-fifths of the number recorded.

5. *Juniors.*—(1) The class of Juniors shall consist of graduates of technical schools of established reputation, or persons who have had not less than two years' practical experience in marine engine works or shipyards.

(2) Candidates must be at least eighteen years of age and certify their intention to continue in the profession and become naval architects or marine engineers.

(3) Juniors shall be eligible for transfer to the class of Members or Associates after fulfilling the necessary conditions; when they are twenty-eight years of age they shall be offered the option of being transferred to the class of Members or Associates in conformity with their qualifications; but if they do not accept such offer or do not qualify, they shall be dropped from the rolls of the Society.

(4) The admission of Juniors shall be by a favorable vote of three-fourths of the members of the Council present.

(5) Juniors shall have no voice in the government of the Society or admission of members.

6. *Honorary Members and Honorary Associates.*—The Council may elect Honorary Members and Honorary Associates, the total number not to exceed twenty-five. They shall be persons of acknowledged eminence in their profession upon whom the Council may see fit to confer an honorary distinction.

7. *Benefactors and Permanent Members.*—The Council may establish a list of Benefactors. It may also elect as Permanent Members of the Society such Members or Associate Members as shall, in the opinion of the Council, by reason of notably liberal contributions to the Society, merit special recognition. Permanent Members shall, from the date of their election, be relieved from annual dues, and shall have the right, subject to the approval of Council, to designate by will or otherwise, their successors. The conditions to be met before placing any name on the list of Benefactors and the regulations governing the election of Permanent Members shall be prescribed by the Council.

Article III.

Dues, Suspension and Expulsion of Members.

1. The entrance fees, payable on admission to the Society, shall be as follows:

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no fees.

2. The annual dues shall be as follows:

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Asociates, no dues.

3. A member transferred from one grade to another shall pay the difference between the entrance fees of the two grades, and his annual dues shall be those of the grade to which transferred.

4. The annual dues shall be payable in advance on the first day of January. The Secretary shall notify each member of the amount due for the ensuing year at the time of giving

notice for the annual meeting. On notification of his election each member shall pay his entrance fee, but annual dues for the current year shall not be required unless he desires to receive the published transactions of the Society for that year, in which case he shall pay five dollars in addition to the entrance fee.

5. Members and Associates can compound for all future dues and become Life Members or Life Associates by making a single payment of two hundred dollars and signing an agreement to conform to any future amendments to the Constitution and By-Laws.

6. Members are entitled to no return of fees upon severing their connection with the Society.

7. Any member whose dues are more than three months in arrears shall be notified by the Secretary. Should his dues become six months in arrears he shall be again notified by the Secretary and his rights as a member suspended. Should his dues become one year in arrears the delinquent member shall forfeit his membership in the Society unless the Council may deem it expedient to extend the time of payment.

8. The Council may, in its discretion, temporarily suspend the annual payment of dues by any member whose circumstances have become such as to make such payment impossible, and may, under similar circumstances, remit the whole or part of dues in arrears.

9. No name shall be entered on the rolls as Member, Associate or Junior, nor shall the privileges of membership be enjoyed until the payments required in paragraphs 1 to 4 of this article have been made; if the payment be delayed for more than six months from the date of election, the same shall be void unless the Council otherwise direct.

10. (1) Should the expulsion of any member be judged expedient by five or more members, they must draw up and sign a proposal requesting such expulsion, delivering the same to the Secretary, to be laid before the Council.

(2) If the Council do not find reason to concur in the proposal, no entry thereof shall appear in the minutes, nor shall any public discussion thereon be permitted.

(3) If, however, the Council find the charges contained in the proposal for expulsion substantiated, the accused member shall be notified and given an opportunity to resign. If he avails himself of this privilege, no entry shall be made on the minutes nor public discussion in the case be permitted. But if he declines to resign and offers no satisfactory explanation of the charge, the whole case shall be submitted to a special meeting of the Society.

(4) If two-thirds of the members at this special meeting (providing there be not less than twenty present) vote for expulsion, the Chairman of the meeting shall cause the accused to be expelled from the Society, and direct the Secretary to notify the accused of this action.

Article IV.

Officers.

1. The officers of the Society shall consist of a President, Past Presidents, Honorary Vice-Presidents, twelve Vice-Presidents, twenty-four members of Council, and a Secretary and Treasurer.

2. Both Members and Associates are eligible for the offices of President, Honorary Vice-President, Vice-President and members of Council, but three-fourths of the Council shall be Members.

3. Prior to the date of the annual meeting of the Society of the year with which the term of the President expires, the Council shall nominate a candidate for the office of President, whose name shall be presented to the Society for election at the annual meeting. Any other candidate whose nomination, signed by at least sixty Members and Associates, shall have been submitted to the Secretary prior to the annual meeting shall also be presented. The candidate receiving the highest number of votes shall be the President for the ensuing three years. The first President under this rule was elected at the annual meeting in 1906 and his term of office began January 1, 1907. The President shall not be eligible for election as his own successor.

4. (1) The term of office of the Vice-Presidents shall be three years. The terms of the Vice-Presidents which, under a previous provision of the Constitution, should have expired in 1911 and 1912 are regarded as having expired on December 31, 1911. Those terms which, under the same conditions, should have expired in 1913 and 1914 are regarded as having expired on December 31, 1912; those which should have expired in 1915 and 1916 are regarded as having expired on December 31, 1913. Beginning with the four Vice-Presidents elected for the term ending December 31, 1914, there shall be four Vice-Presidents elected each year to take the place of those whose terms expire. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election.

(2) Honorary Vice-Presidents shall be chosen from the list of Vice-Presidents who have had at least ten years' service as Vice-President. They shall be chosen at the meeting of the Council next prior to the annual general meeting of the Society and must be the unanimous choice of all members of Council present. Not more than two Vice-Presidents may be elected Honorary Vice-Presidents in any one year.

5. (1) The term of office of the Members and Associate Members of Council shall be three years. Prior to August 1 of each year the Secretary shall mail to each Member and Associate a list of the names of the Members and Associate Members of Council whose terms expire with the current year, and shall enclose a blank on which each Member may, if he so desires, nominate one additional candidate for Member of Council and one additional candidate for Associate Member of Council; and each Associate Member may, if he so desires, nominate one additional candidate for Associate Member of Council. No nominations received by the Secretary after August 31 shall be considered.

(2) Prior to September 1 of each year the President shall appoint a nominating committee of five, at least three of whom shall be Members. This committee shall scrutinize the nomination slips sent in by Members and Associates and prepare a ballot. This ballot shall contain the names of all the retiring Members and Associate Members of Council who shall not have declined re-election and a sufficient number of additional names to make a total of nine candidates for Member of Council and three candidates for Associate Member of Council. The names listed on the ballot, other than those of retiring Members and Associate Members of Council, shall be chosen by the nominating committee from those who have received the highest number of votes on the nominating lists returned by members of the Society.

(3) Should the number of names which have received at least ten votes in the case of nominees for Members of Council and five votes in the case of nominees for Associate Members of Council be insufficient to complete the number on the ballot list above provided for in sub-paragraph (2), the nominating committee shall add enough names to bring the

total on the ballot up to nine candidates for Member and three candidates for Associate Member of Council.

(4) The ballots shall be sent by mail as soon as possible after September 1 of each year to all Members and Associate Members of the Society. Each Member may vote for not more than six Members of Council and two Associate Members of Council, and each Associate may vote for not more than two Associate Members of Council. The ballots shall be returned by mail to the Secretary and canvassed by a committee of three members appointed by the President. This canvassing committee shall report the results of the election to the Council at its meeting immediately prior to the Annual Meeting of the Society.

(5) When the ballots have been sent out by the Secretary, should there be a desire on the part of Members or Associates to suggest another list of candidates for the Council, any twenty Members and Associates may unite in submitting another list to the Secretary which shall also be sent out to the membership to be considered in connection with the list already sent. In any event, the six Members who receive the highest number of votes shall be declared elected Members of Council, and the two Associates receiving the highest number of votes shall be declared elected Associate Members of Council, in each case for a term of three years.

6. A vacancy in the office of President shall be filled by ballot by the Council from the list of Past Presidents, Honorary Vice-Presidents and Vice-Presidents until the end of the year in which it occurs. At the annual meeting of that year a new President shall be elected for three years in the manner prescribed in paragraph 3. A vacancy in the office of member of Council shall be filled by the Council for the unexpired portion of the term of the Member or Associate causing the vacancy.

7. The President, Past Presidents, Honorary Vice-Presidents and Vice-Presidents shall be *ex-officio* members of Council.

8. The Council may hold meetings subject to the call of the President, as often as the interests of the Society may demand.

9. At all meetings of Council seven members shall constitute a quorum.

10. The Secretary and Treasurer shall be elected annually by the Council, but may be removed at any time by a majority vote of the Council after due notice has been given.

11. The Secretary must be a Member of the Society.

Article V.

Management.

1. (1) The President shall have general supervision over the affairs of the Society, appoint special committees, and preside at the annual general meetings. He shall be *ex-officio* member of all committees.

(2) In the absence of the President, one of the Past Presidents, Honorary Vice-Presidents or Vice-Presidents, in the order of seniority as determined by original accession to, or election in, their respective grades, shall preside and perform all the duties of the President; where there is the same date of seniority, the alphabetical order will govern. Provided, however, that for the Annual Meeting of the Society or for any other special occasion when it is known that the President cannot attend and preside, the Executive Committee shall, in its discretion, select and designate as Acting President any one of the Past Presi-

dents, Honorary Vice-Presidents, Vice-Presidents or members of Council, who shall act for the President in his temporary absence and shall perform all the duties which would devolve upon that officer during such Annual Meeting or on such special occasion.

2. (1) The direct management of the Society shall be vested in an Executive Committee of seven, composed of five members of Council, elected annually by the Council, and the President and the Secretary of the Society *ex-officio*. At least three of the five elective members of the committee shall be Members of the Society.

(2) Meetings of the Executive Committee may be held at any time, subject to the call of the Chairman; and four members shall constitute a quorum for the transaction of any business that may be properly brought before the Committee.

3. The Executive Committee shall manage the affairs of the Society in conformity with the laws under which it is incorporated and the provisions of this Constitution. It shall direct the investment and care of the funds of the Society; make appropriations for specific purposes; arrange for the reading and publication of professional papers; take measures to advance the interests of the Society, and generally direct its affairs under such regulations as the Council may from time to time prescribe.

4. The Executive Committee shall make an annual report to the Society, transmitting the report of the Secretary and Treasurer, and of any special committee which may have been ordered.

5. (1) The Secretary shall be the Executive Officer of the Society under the immediate direction of the President and the Executive Committee.

(2) He shall prepare the business for the annual meetings and record the proceedings thereof.

(3) He shall be responsible for all expenditures and certify the accuracy of all bills or vouchers upon which money has been paid, and he shall conduct the correspondence of the Society and keep full records of the same.

6. The Treasurer shall see that all money due the Society is collected and carefully invested in such manner as the Executive Committee may direct. If considered advisable by the Council, the duties of Treasurer may be performed by the Secretary.

7. The accounts of the Secretary and Treasurer shall be audited annually in such manner as the Executive Committee may direct.

Article VI.

Meetings.

1. There shall be at least one annual general meeting of the Society for the reading and discussion of professional papers, election of officers for the ensuing year, and transaction of such other business as may be brought before it. The time and location of this meeting shall be determined by the Council at least three months prior to the date fixed.

2. Special meetings may be called by the Executive Committee at the request of twenty members, which request shall state the purpose of the meeting. The call for such meetings shall be issued ten days in advance, and shall state the purpose thereof. At these meetings thirty members shall constitute a quorum.

3. The Society may adopt, from time to time, such rules as it may think proper for the order of business at its meetings.

Article VII.

Regulations and By-Laws.

1. The Council shall have authority to establish such by-laws and regulations as may be necessary for the government of the Society in the conduct of its affairs, provided that such by-laws and regulations do not conflict with the provisions of this Constitution and that they are approved by a two-thirds vote of the members of Council present at any meeting regularly called for the consideration of same. If, however, objection be made by any member of Council to a by-law or regulation so proposed, it must be submitted in writing for the action of the entire Council and will not be finally adopted unless a majority of the Council signifies its approval.

Article VIII.

Amendments.

1. Proposed amendments to the Constitution must be reduced to writing and signed by not less than ten members. They shall be forwarded to the Secretary at least ten days before the annual general meeting, and shall be immediately forwarded to the Council for its consideration. If a majority of the Council approve the proposed amendment it shall be presented to the Society at the next ensuing general meeting for discussion; if approved by two-thirds of the members present, voting by ballot, if a ballot be demanded, it shall be adopted.

INTRODUCTORY PROCEEDINGS

MINUTES OF THE TWENTY-THIRD ANNUAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, HELD AT THE ENGINEERING SOCIETIES BUILDING, NEW YORK CITY, THURSDAY AND FRIDAY, NOVEMBER 18 AND 19, 1915.

FIRST SESSION.

THURSDAY MORNING, NOVEMBER 18, 1915.

The President, Mr. Robert M. Thompson, called the meeting to order at 10:30 a.m.

THE PRESIDENT:—The first order of business is the presentation of the report of the Secretary-Treasurer.

Mr. Cox presented the following report:—

REPORT OF SECRETARY-TREASURER.

NOVEMBER 18, 1915.

To the Council of The Society of Naval Architects and Marine Engineers:—

GENTLEMEN:—I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1915.

The membership of the Society November 1, 1915, was as follows:—

Class of Members.	Membership, November 1, 1914.	Elected at 1914 Meeting.	Promotions, Members to Life Members.	Promotions, Associates to Members.	Promotions, Juniors to Members.	Suspended by Council.	Membership at close of Annual Meeting, 1914.	Deaths, 1914-1915.	Resignations, 1914-1915.	Membership, November 1, 1915.
Members	564	35	—1	+4	+1	11	592	11	7	574
Associates	190	9	—	—4	—	—	195	5	6	184
Juniors	11	3	—	—	—1	—	13	1	—	12
Life Members	5	—	+1	—	—	—	6	—	—	6
Life Associates	4	—	—	—	—	—	4	—	—	4
Honorary Members	1	—	—	—	—	—	1	—	—	1
Honorary Associates	2	—	—	—	—	—	2	—	—	2
Totals	777	47	—	—	—	11	813	17	13	783

Receipts.

From November 1, 1914, to October 31, 1915, inclusive.

Entrance fees of new members for the year ending December 31, 1915:		
Life Members	$200 00	
Members	355 00	
Associates	70 00	
Juniors	15 00	
		$640 00
Dues for the year ending December 31, 1915:		
Members and Associates	$6,350 00	
Juniors	35 00	
		6,385 00
Dues for the year ending December 31, 1914:		
Members and Associates	$880 00	
Juniors	15 00	
		895 00
Dues for the year ending December 31, 1913:		
Members and Associates	$170 00	
Juniors	10 00	
		180 00
Dues for the year ending December 31, 1912:		
Members and Associates		60 00
Dues for the year ending December 31, 1911:		
Members and Associates		30 00
Dues for the year ending December 31, 1910:		
Members		10 00
Members' dues in advance for the year ending December 31, 1916		30 00
Sales of publications:		
Society transactions to members and dealers	$898 25	
Special editions of papers	99 50	
		997 75
Exchange on remittances, members' dues		9 05
Banquet, Annual Meeting, 1914		1,175 00
Panama fund		550 00
Interest:		
On municipal bonds, City of New York	$332 50	
On bank balances and certificates of deposit, Franklin Trust Company	35 45	
		367 95
Total receipts		$11,329 75
Balance cash in bank and on hand, November 1, 1914		3,263 30
		$14,593 05

STATEMENT.

DISBURSEMENTS.

From November 1, 1914, to October 31, 1915, inclusive.

Publications:		
Printing Volume 22	$4,004 80	
Printing Membership Year Book	146 90	
Binding old volumes	91 30	
Forwarding volumes and papers	66 56	
Storage of volumes	120 40	
Miscellaneous printing	31 89	
		$4,461 85
Rent of safe deposit box, Franklin Trust Company		5 00
Expenses, 22nd Annual Banquet, December, 1914		1,062 60
Expenses, 22nd Annual Meeting, December, 1914		453 99
Exchange on remittances, members' dues		8 57
Salaries and clerical expenses		1,380 00
Audit of books and accounts to November 1, 1914		180 00
Rent of Society rooms		310 82
Office expenses, postage, stationery, etc.		775 84
Engineering Congress		500 00
Investment:		
Purchase of certificate of deposit, Franklin Trust Co		1,000 00
Total disbursements		$10,138 67
Balance cash, October 31, 1915:		
In Franklin Trust Company	$4,425 42	
On hand	28 96	
		4,454 38
		$14,593 05

DEATHS (17).

Members (11).

A. J. Du Bois.
Charles A. Harrington.
Henry S. Hayward.
John B. Herreshoff.
Albert L. Hopkins.
Constantine Jansson.
Leopold Katzenstein.
John Loyd.
Alexander J. Maclean.
Frederick G. Rogers.
Charles Ward.

Associates (5).

Jacob R. Andrews.
Ransford D. Bucknam.
Harrison B. Moore.
Edward Smith.
D. S. Vassilieff.

Junior (1).

Revere B. Pulsifer.

RESIGNATIONS (13).

Members (7).

Luigi Barberis.
George R. Ferguson.
Lyman J. Hewins.
Herman Konitzky.
James Montgomerie.
A. Appleton Packard.
Walter B. Tardy.

Associates (6).

Calvin Austin.
Winthrop Cole.
Charles M. Heald.
Alexander F. Jenkins.
Thomas C. McLean.
Frederick A. Meyer.

The following delinquencies exist in the payment of dues:—

For the year ended December 31, 1911:—		
Associates		$10 00
For the year ended December 31, 1912:—		
Members	$52 00	
Associates	75 00	
		127 00
For the year ended December 31, 1913:—		
Members	$220 00	
Associates	120 00	
Juniors	10 00	
		350 00
For the year ended December 31, 1914:—		
Members	$400 00	
Associates	200 00	
Juniors	10 00	
		610 00
For the year ended December 31, 1915:—		
Members	$1,120 00	
Associates	420 00	
Juniors	30 00	
		1,570 00
Total outstanding dues at October 31, 1915		$2,667 00

Statement of Resources and Liabilities.

RESOURCES.

Membership dues after deducting for deaths and resignations ($155) and for doubtful accounts ($200)		$2,312 00
Accrued interest on municipal bonds		157 50
Due from dealers for volumes		648 00
Office furniture and equipment at 30 per cent reduction from cost		885 00
Publications on hand at 50 per cent reduction from cost, excepting Volumes 18, 19, 20, 21 and 22		5,291 34
Investments:—		
Municipal Bonds at par	$12,000 00	
Certificates of Deposit, Franklin Trust Company	3,000 00	
		15,000 00
Cash on deposit, Franklin Trust Company	$4,425 42	
Cash on hand	28 96	
		4,454 38
Total resources		$28,748 22

LIABILITIES.

Membership fees and dues paid in advance	$30 00	
Panama Fund	565 00	
Total liabilities		595 00
Society's present worth at October 31, 1915*		$28,153 22

*By the provisions of the Endowment Fund resolution adopted at the annual meeting held in December, 1914, the position of the Society's present worth at October 31, 1915, is as follows:

Net assets, excluding Endowment Fund			$15,023 22
Endowment Fund:			
Investments in municipal bonds, par value		$12,000 00	
Additions to Endowment Fund, 1914–1915:			
Membership entrance fees	$640 00		
Investment income	490 00		
		1,130 00	
			13,130 00
			$28,153 22

The financial statements have been verified by Wechsler & Mills, Public Accountants of New York.

Respectfully submitted,

DANIEL H. COX,
Secretary-Treasurer.

Mr. Cox:—The report, as usual, has been printed and distributed to the members, and it is not customary to read it in detail. I might give a summary of the important features. As regards membership, the results are satisfactory. We are coming to the meeting with 784 members, where we came to the meeting last year with 777, and unfortunately we suffered a very heavy loss by death during the past year, so that the membership of the Society is increasing, at least. As you will see later, during the morning, there have been at least as many new applicants, if not more than usual.

As regards delinquencies, the affairs of the Society are favorable, compared with the usual condition. In our resignations we have not suffered as heavily as usual.

Turning to the financial statement, commencing on page xxvi, the receipts are given in detail, and one new matter has entered into the statement, namely, the formation of an Endowment Fund—the setting aside of a certain amount of the Society's permanent fund, not for the use of current expenses. That is touched upon on page xxix. According to the instructions issued by the Society last year, toward this fund were to be applied the Society's present investments amounting to $12,000 in bonds, all annual receipts under the heading of membership entrance fees, and the income from the present investment. The sales of publications have been slightly in excess of the usual amount. The banquet receipts and disbursements show a very favorable comparison, we having a small credit balance instead of an excess on the other side of the ledger.

Under the heading of the Panama Fund we still have in hand $565. We have already paid to the Panama-Pacific International Engineering Congress $1,000, two payments of $500 each. It is anticipated that there will be one further payment, but we are informed that certainly will not exceed $500, and it is possible it may be less. This entire matter has not been handled by the working capital of the Society, but from funds received by voluntary subscription from the members at large.

Under the heading of "Disbursements" the cost of the Transactions for the past year was a little in excess of the preceding year, but the current expenses in general are about as usual.

Our only liabilities are the small sum of membership fees and dues paid in advance and the Panama Fund matter.

I may say that during the year the present president has joined the ranks of Life Members of the Society.

I think, with these explanations, the report may be acted on.

The President:—This report has been presented to the Council and has been recommended for adoption and approval. What will be your disposition of it? If I hear no objection, the report will be considered as adopted and placed on file. I hear no objection. The report will be placed on file, as adopted.

Gentlemen, *In Memoriam!* You will please rise.

The Secretary:—During the past year the following members have passed away (the Secretary then read the list of names of deceased members, while the members of the Society stood in silence).

The President:—At the meeting of the Council the following gentlemen were elected as Vice-Presidents for the term expiring December 31, 1918:—H. I. Cone, Lewis Nixon, G. W. Dickie and G. E. Weed.

For Members of Council, term expiring December 31, 1918:—H. A. Magoun, W. J. Baxter, Andrew Fletcher, R. H. Robinson, W. D. Forbes and W. G. Coxe.

For Associate Members of Council, term expiring December 31, 1918:—J. S. Hyde and H. D. Goulder.

For Executive Committee:—W. L. Capps, Lewis Nixon, W. I. Babcock, Andrew Fletcher and W. M. McFarland.

For Secretary-Treasurer:—D. H. Cox.

For Committee on Papers:—W. M. McFarland, W. I. Babcock and F. L. DuBosque.

The Committee on Nominations will now report their recommendations for President.

Chief Constructor Washington L. Capps, *Vice-President*:—Gentlemen, the Committee on Nominations for the presidency of this Society felt that it had a special duty to perform this year, in view of the fact—of which many of you may be aware, but which I beg particularly to bring to your attention—that during our next three-year period of the presidency, we hope to celebrate the twenty-fifth anniversary of the foundation of the Society. This Society was organized, under a charter of the State of New York, on the 28th of April, 1893, on petition of certain charter members. The petition was approved by Justice Patterson of the Supreme Court of New York on the 10th day of May, 1893, and our first meeting was held in November of that same year. So that those of us who are here in November, 1918, will be privileged to participate in a notable anniversary. It therefore seemed to the Committee on Nominations eminently proper that the one to be nominated for the presidency this year should be one who had been identified with the Society from its inauguration, and, if practicable, one who had occupied high place in the Council during this whole period. In this connection, it is regretfully noted that not a single one of our original vice-presidents is living, and our dearly-beloved first president, as you know, passed to the great beyond several years ago.

Fortunately for us, however, we have in our Council today one who, from the very beginning of this Society, has taken a most active interest in its work. He is known to all of you; he is loved by all of you. The committee, therefore, has not the slightest hesitation, in spite of its knowledge that it would add to the work of this particular gentleman and impose a further considerable burden upon him—your committee, I repeat, had not the slightest hesitation in recommending by unanimous vote to the Council that their selection for the presidency be submitted to the general meeting of the Society. The Council received the committee's recommendation with acclaim and I now consider it a very great privilege to present to you, as the nominee of the Council for the presidency, our honored and beloved colleague, Mr. Stevenson Taylor. (Applause.)

The President:—Gentlemen, you have heard the report of the Nominating Committee. As no other nomination has been made, under the provisions of the by-laws, Mr. Taylor's name is the only name before you. I shall, therefore, ask for a rising vote as to whether the report of the committee shall be accepted and adopted and Mr. Stevenson Taylor elected president. All in favor of that, make it manifest by rising. If there are any opposed, they will please rise. I see no one rising. It is a unanimous vote, and Mr. Stevenson Taylor can be congratulated upon the confidence, the love and respect his associates have shown toward him in electing him the president of the Society for the ensuing term of three years.

MR. STEVENSON TAYLOR:—Mr. President and gentlemen, I am deeply touched by the confidence shown in me, first by the members of the Council, and now by the members of the Society. I have only to say further that I will endeavor to do in the future what I have endeavored to do in the past—the best I can for the good of the Society. I thank you all very much for your confidence. (Applause.)

THE PRESIDENT:—The Secretary will read the list of applicants for membership recommended by the Council.

THE SECRETARY:—At the meeting of the Council held yesterday afternoon, the following applications for members of various grades and transfers from one grade to another were considered and favorably passed upon. The names are therefore submitted to the Society-at-large, with a recommendation by the Council that they be elected to the following grades:—

Life Associate Member.

Robert M. Thompson, 43 Exchange Place, New York, N. Y.

Members (22).

Cornelius A. Binks, Superintending Engineer, N. Y. & Cuba Mail S. S. Company, New York, N. Y. P. O. address, Mattawan, N. J.

Frederick H. Chase, Naval Architect, Tams, Lemoine & Crane, 52 Pine Street, New York, N. Y.

Andrew W. Christian, Assistant to President, Harlan & Hollingsworth Corporation, 526 Bourse Building, Philadelphia, Pa.

Niels Christiansen, Superintendent of Machinery, Newport News Shipbuilding & Dry Dock Company, Newport News, Va.

Albert C. A. Holzapfels, Vice-President, Holzapfels, Ltd., 18 Broadway, New York, N. Y.

Russell C. Jones, Manager, Marine Department, Griscom-Russell Company, 90 West Street, New York, N. Y.

George F. Lawley, President, George F. Lawley & Son Corporation, Neponsett, Mass.

Johan H. Lindroos, Draughtsman, Cox & Stevens, 15 William Street, New York, N. Y. P. O. address, 4124 8th Avenue, Brooklyn, N. Y.

John S. Leitch, General Manager, Collingwood Shipbuilding Company, Collingwood, Ont.

David Millar, Surveyor, Lloyd's Register of Shipping, 1119 Munsey Building, Calvert Street, Baltimore, Md.

Joseph F. Moran, Vice-President, Atlantic Basin Iron Works, 11 Imlay Street, Brooklyn, N. Y.

Kurt A. W. Orbanowski, Naval Architect, 140 Broadway, New York, N. Y.

Evangelos D. Papayannis, Naval Constructor, Royal Hellenic Navy, care of Ministry of Marine, Athens, Greece.

William W. Smith, Engineer, Westinghouse Machine Company, East Pittsburgh, Pa.

John F. Wentworth, Draughtsman, Navy Yard, Boston, Mass.

Cecil W. Weaver, Marine Supervisor, Pusey & Jones, Wilmington, Del.

Ludwig Anderssen, Ship and Engine Surveyor, 80 Broad Street, New York, N. Y.

Henry Holmes, Assistant Engineer, Esplen & Sons, Produce Exchange Building, New York, N. Y. P. O. address, 807 Eighth Avenue, Brooklyn, N. Y.

James McNaught, Manager, Esplen & Sons, 20 Produce Exchange Building, New York, N. Y. P. O. address, 9 Prospect West, Brooklyn, N. Y.

Frederick J. Smith, Superintendent, Machine Shop, Robins Dry Dock & Repair Company. P. O. address, 307 Sherman Street, Brooklyn, N. Y.

Louis N. Lacombe, Assistant Superintendent, Robins Dry Dock & Repair Company, Brooklyn, N. Y. P. O. address, 451 56th Street.

Samuel Bennett, Surveyor, American Bureau of Shipping. P. O. S. Box 438, Newport News, Va.

Associate to Member (1).

Frederick S. Brinton, Naval Architect, 22 Colman Dock, Seattle, Wash.

Associates (8).

Norman R. Dutton, Designer, Marine Machinery, Pusey & Jones Company, Wilmington, Del.

Charles F. de Ganahl, President, Tampico Navigation Co., 80 Broad Street, New York, N. Y.

James A. Guthrie, Jr., Marine Adjuster, Insurance Department, Pennsylvania Railroad Company.

Von-Fong Lam, Student, Massachusetts Institute of Technology, Boston, Mass. P. O. address, 156 Huntington Avenue.

John A. McGregor, President, Union Iron Works Company, San Francisco, Cal.

Charles H. Macdonald, Representative, Art Metal Construction Company, 1460 Woolworth Building, New York, N. Y.

Leigh R. Sanford, U. S. Engineer Office, Rock Island, Ill.

Henry E. Rossell, Assistant Naval Constructor, U. S. Navy, Navy Yard, New York, N. Y.

Juniors (6).

Henry C. Adams, Jr., Shipfitter, New York Shipbuilding Company, Camden, N. J.

Clay L. Jennison, Draughtsman, U. S. Coast Guard, Treasury Department, Washington, D. C.

Carl E. Petersen, Draughtsman, Morse Dry Dock & Repair Company, Brooklyn, N. Y.

Philip H. Thearle, Draughtsman, San Diego Marine Construction Company, San Diego, Cal.

George Laing, Jr., Surveyor, The Vessel Agency, 58 Maiden Lane, New York, N. Y. P. O. address, 31 Trinity Place, West New Brighton, N. Y.

Linn M. Rakestraw, Student, University of Michigan. P. O. address, 1316 Geddes Avenue, Ann Arbor, Mich.

THE PRESIDENT:—You have heard the names read, which have all been recommended to you by the Council. Any member has the right to demand a ballot on any name. Does

any member demand a ballot? Not hearing any demand for the ballot, I put the question to you: Shall the men whose names have been read to you as applicants for membership be elected? The Chair declares that at least four-fifths of the members present have voted in the affirmative and they are elected.

For Associate Members, I put the question to you: Shall the men whose names have been read as applicants for Associate Members be elected? Any member has a right to demand a ballot on any name. Does any member demand a ballot? Not hearing any demand for a ballot, all in favor of electing the men whose names have been read as Associate Members please vote "Aye;" contrary-minded, "No." The Chair declares that four-fifths of the members present have voted in the affirmative and the gentlemen are duly elected as Associate Members.

For Junior Members, I put the question to you: Shall the applicants whose names have been read be elected to Junior Membership? All in favor, make it manifest by saying "Aye;" contrary-minded, "No." The Chair declares that at least four-fifths of the members present have voted in the affirmative, and the applicants are duly elected as Junior Members.

PRESIDENT'S ADDRESS.

Gentlemen of the Naval Architects and Marine Engineers Society, for the first time since you did me the honor of selecting me to be your president, the state of my health permits of my being with you at your annual meeting. May I take this opportunity of thanking each and all of you for the honor conferred upon me, for the uniform kindness and sympathy with which you have treated me and condoned my inability to perform my duty. To those gentlemen who have accepted the responsibilities and done the work that I should have done my thanks have already been given, but it is a pleasure here to renew them.

During the past year the thoughts of all have been centered upon the European war. Many new inventions cognate to our profession have been exploited and developed. The submarine has come into great prominence, and for a time seemed to be a weapon of the first order, but, like the pen, it must be in the hands of men entirely great to supplant the older methods of destruction.

The aeroplane, following the earlier precedents of the bicycle and automobile, was first a toy, but has rapidly become a tool. The German Zeppelins, avowedly used to create terror, have failed to produce the effect intended. It has been demonstrated that they can under favorable conditions navigate the air and reach the point at which they aim; but, so far, they have failed to accomplish anything of value from a military point of view. They have destroyed a few buildings, they have killed some women and children and a few men, and they have helped the English recruiting sergeants by the wave of anger following their raids.

The battle cruisers, vessels of great speed, carrying large guns, and but lightly armored, have apparently made good, although they have not been put to the final test of a fleet engagement.

The battleships have, perhaps, made the best showing, for the English battle fleet, resting quietly in harbor, has by its potential force kept the sea clear of German and Austrian ships. To us this is the most important lesson of the war. A fleet to be of value must be equal, or nearly equal, to the opposing force it may have to meet. The modern engines of destruction are so tremendous that any great excess in the number of these machines assures the defeat and wiping out of the opposing fleet.

Notwithstanding unfavorable legislation the shipyards in the United States have been unusually active during the last twelve months, as will be seen from the following statement of vessels under construction during this period.

The statistics of the Department of Commerce show the following vessels under construction on July 1, 1915:—

	Merchant Vessels.		*Government Vessels.*	
	No.	*Tons.*	*No.*	*Tons.*
Seacoast yards	62	294,138	54	184,732
Great Lakes and rivers yards..	14	15,951	15	6,058
Totals	76	310,089	69	190,790

No official records of contracts placed since that date are available, but it is a fact that at the present moment there is scarcely a building berth available either in the sea coast or Lake yards, and that shipowners now ordering new tonnage will for the most part have to be satisfied with delivery in 1917. It is interesting to note that a large proportion of these new vessels are to be used in the carriage of oil in bulk.

The main cause of this increase in shipbuilding may be laid to the European war, as the withdrawal for many reasons of so large a proportion of the world's tonnage created a condition most favorable to the shipowners in this country. Were it not for the harassing legislation existing against shipowners and ship operators, no doubt much more capital would have been attracted to the shipbuilding industry, but we should be thankful that the yards are benefited to a very considerable degree.

In marine engineering the use of fuel oil in place of coal is becoming more and more general. The geared turbine, which has been used abroad successfully for many classes of vessels, is now commencing to be used in this country also with pronounced success. The use of the straight-drive turbine for high-speed vessels continues to be entirely satisfactory. Electrical drive is being carefully investigated and developed, and the Navy Department has lately specified one of the new battleships to be propelled in this manner.

The Diesel engine continues to be largely used for submarines, but its general use has not been greatly developed. The semi-Deisel or hot-bulb engine, approximating to the regular Diesel in efficiency, is commencing to be a strong competitor and is replacing steam in many instances where the power to be installed is not excessive.

As there are so many and such important papers to be read and discussed, I will not further occupy your time, and will now proceed with the regular order of business.

The President:—The first paper to be taken up at this session is No. 1, entitled "Aerodynamical Experiments upon a Yacht's Mainsail," by Prof. H. A. Everett, Member of the Society. We will now have the paper.

Professor H. A. Everett, *Member:*—Mr. President and members of the Society, as this paper is rather brief, I will ask the indulgence of the Society if I read the major part of it *in extenso.*

AERODYNAMICAL EXPERIMENTS UPON A YACHT'S MAINSAIL.

By Professor H. A. Everett, Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

The following experiments were carried out in the Aerodynamical Laboratory of the Massachusetts Institute of Technology in January, 1915, and were undertaken primarily to determine the possibility of obtaining by this means reliable information concerning the action of sails in the wind. The work resulted in the determination of the location of the true center of pressure, the normal pressure per unit of area for a given wind velocity, and the proper angle of boom to center line for fastest sailing on a given course (Plate 12).

The experiments were carried out with a single sail (a mainsail), as the adoption of two (as jib and mainsail) would have injected an indeterminate feature, the interrelationship between them due to variations in sheet trimming. The sail used (Plates 1 and 2) was an exact reproduction of a successful sail as used on one of last season's, class P, racing yachts, and was made accurately to the scale of $\frac{3}{8}$ of an inch to 1 foot out of light, firm China silk. It was made out of a single piece of silk, no attempt being made to reproduce seams, but the roach at the leach of the sail was the maximum which the rule permits and was held out by miniature battens. The sail was carefully cut and made by Wilson & Silsbee in exact conformity with their cutting plan for the full-sized sail.

In carrying out the tests it was considered undesirable to have any sort of body under the sail to which the main sheet could be made fast, as this would inject a disturbing factor into the action of the wind on the sail by disturbing the air flow to the sail, therefore the boom (of $\frac{3}{16}$-inch steel tubing) was rigidly attached to the mast (of $\frac{5}{16}$-inch steel tubing) at an angle which represented the normal setting of the sail. The gaff was free to swing off and take up whatever position the wind drove it into (see Plate 2). The sail was set by throat and peak halyards as nearly as possible in exact conformity with the setting of the actual sail. The sail was provided with battens correct to scale, the attachment to the boom and gaff was by the customary lace lines, and the luff was held to the mast by small brass rings. The sail was vertical at all times, no attempt being made to simulate heel.

The experiments were made possible by the facilities of the aerodynamical laboratory or "wind tunnel" recently established at the Institute in connection with the Department of Naval Architecture under Prof. C. H. Peabody. Their successful conclusion was largely dependent on the hearty cooperation of Assistant Naval Constructor J. C. Hunsaker, who is in direct charge of the aeronautical instruction and this laboratory.

A detailed description of the laboratory is given in the Appendix. Suffice it to say here that it consists of a square duct 4 feet on a side through which a current of air is drawn at uniform velocity with a balance under it which supports the models to be tested and weighs the different forces acting on them (Plate 3).

The method of carrying out the observations was to set the sail with the plane of the boom and mast parallel to the center line of the wind tunnel, then by turning the boom upstream to known angles with the center line to measure the torque and the moments of the thrust, in the direction of the wind and at right angles to it. A plane passed through the boom and mast was considered the plane of reference for all settings. The twisting moment or torque about the mast was measured by the torsional distortion of a calibrated wire in the extension of the axis of the mast (see Plate 4). The balance which was used for this work (Plate 5) is a copy of the one in use in the National Physical Laboratory in Great Britain, and was built under their direction by the Cambridge Scientific Instrument Company especially for the Institute. It is a remarkable combination of ingenuity and extraordinary instrument-making skill, and has been used extensively for the regular aerodynamical experiments carried out in the laboratory. The observations for thrust and torque were taken for each angle with the speed of the wind maintained constant at 15.1 miles per hour. When the observations of thrust had been completed for all angles the settings were repeated at the same wind velocity for measurements of torque or moment about the mast, as both thrust and moment cannot be measured simultaneously on the balance.

In order to determine the effect of varying wind intensity some of the runs were repeated for winds of approximately 10 miles and 20 miles per hour. It was thought that intermediate points could be filled in by cross fairing from the similar curves derived for 15 miles per hour.

Observations were taken of the moment of the component of the wind pressure on the sail acting along the wind (d) and of the moment of the component acting across the wind (c) and of the moments of the resultant or total pressure about the mast. This gave four equations (1, 3, 5, 6, Plate 4) which, however, contained five unknowns. By repeating the (c) and (d) observations, with the length of the vertical arm shortened 6 inches, two more equations (2 and 4) were added without increasing the number of unknowns, which resulted in six equations involving five unknowns. The unknowns were: first, the transverse component of the wind pressure (c); second, the down-stream component (d); third, fourth and fifth, the coordinates of the center of pressure x, y and z, measured respectively along the wind, across the wind, and vertically, origin at the intersection of the bottom of the boom with the center line of the mast as shown on Plate 4. The known quantities were the weights on the scale beams, the torque and the length of the weighing arms.

The original observations are given in the first part of Table I.

TABLE I.—*Principal Data and Results.*

θ = Angle of boom to wind.
c_1 = Net cross-wind readings for $a = 30.45$ inches.
c_2 = Net cross-wind readings for $a = 24.05$ inches.
D_1 = Net drift readings for $a = 30.45$ inches.
D_2 = Net drift readings for $a = 24.05$ inches.
M = Moment in inch-pounds.
c = Cross-wind components of forces in pounds.
d = Drift components of forces in pounds.
x = Coordinate of center of pressure along wind in inches.
y = Coordinate of center of pressure across wind in inches.
z = Height of center of pressure above bottom of boom at mast in inches.

θ	Original data.					Results.				
	c_1	c_2	D_1	D_2	M	c	d	x	y	z
15	.308	.256	.090	.076	1.435	.2928	.0788	4.56	1.22	7.80
20	.443	.369	.137	.114	1.950	.4160	.1294	4.32	1.58	7.80
25	.537	.448	.194	.160	2.441	.5004	.1915	4.13	1.93	7.80
30	.574	.478	.258	.213	2.714	.5400	.2532	3.93	2.27	7.80
35	.592	.493	.324	.269	2.887	.5568	.3093	3.72	2.61	7.80
45	.598	.498	.461	.384	3.258	.5624	.4332	3.27	3.27	7.80
55	.574	.478	.602	.504	3.673	.5400	.5512	2.74	3.96	7.80
65	.508	.423	.739	.619	4.093	.4780	.6754	2.11	4.57	7.80
75	.396	.330	.851	.709	4.450	.3712	.7990	1.33	4.96	7.80
90	.175	.146	.975	.816	4.928	.1576	.8946	0	5.29	7.80
110	—.159	—.132	.982	.822	5.120	—.1520	.9004	—1.97	5.28	7.80
130	—.447	—.372	.814	.680	5.160	—.4220	.7540	—3.92	4.64	7.80

NOTE.—For relative positions of center of figure of the sail and the centers of pressure see sail (Plate I)

The solution of the equations (see Plate 4) gave x and y, which are plotted as faired curves on Plate 7, Figs. 4 and 5, and the square root of the sum of their squares gave the distance along the boom at which the resultant pressure may be considered as acting. The location of this point along the boom is shown by Fig. 6, Plate 7, and the height above the boom by Fig. 7, Plate 7. The results from the faired curves are given in the second part of Table I.

The determination of z was perhaps the least precise of any of the characteristics, as its derivation involved the difference between the readings obtained with the arm at its original length and when shortened (see Plate 4, equation 4). In some cases this resulted in a small difference of two large quantities. The location of z as determined is plotted on Fig. 7, Plate 7, and a dotted curve is drawn above and below it to indicate the limits of accuracy which are attributable to the individual points. It is interesting to note that at about 0° and 100° the method became indeterminate because the difference became zero.

TABLE II.

1	2	3	4	5	6	7	8	9	10	11
Angle boom to wind (degrees)	Sq. of comp. cross-wind $(lbs.)^2$	Sq. of comp. down wind $(lbs.)^2$	Resultant pressure on sail (lbs.)		Angle between resultant and wind (degrees)	Supplement of angle between resultant of pressure and boom (degrees)	Angle between resultant of pressure and boom (degrees)	$(Inches^2)$	$(Inches^2)$	Center of pressure aft of c. l. of mast (inches)
θ	c^2	d^2	$R=\sqrt{c^2+d^2}$	$c \div d = \tan.\ \phi$	ϕ	$180° - \alpha = \phi + \theta$	α	x^2	y^2	$\sqrt{x^2+y^2}$
15	.0857	.0062	**.3032**	3.717	74.95	89.95	**90.05**	20.43	1.49	**4.68**
20	.1731	.0167	**.4357**	3.214	72.72	92.72	**87.28**	18.66	2.50	**4.60**
25	.2504	.0367	**.5358**	2.611	69.05	94.05	**85.95**	17.06	3.72	**4.56**
30	.2916	.0641	**.5964**	2.132	64.87	94.87	**85.13**	15.44	5.15	**4.54**
35	.3100	.0957	**.6369**	1.800	60.95	95.95	**84.05**	13.84	6.81	**4.54**
45	.3163	.1877	**.7099**	1.298	52.38	97.38	**82.62**	10.69	10.69	**4.62**
55	.2916	.3038	**.7716**	.980	44.42	99.42	**80.58**	7.51	15.68	**4.81**
65	.2285	.4562	**.8275**	.708	35.30	100.30	**79.70**	4.45	20.88	**5.03**
75	.1378	.6384	**.8810**	.465	24.93	99.93	**80.07**	1.77	24.60	**5.14**
90	.0249	.8003	**.9084**	.176	9.98	99.98	**80.02**	0	27.98	**5.29**
110	.0231	.8107	**.9132**	— .169	— 9.60	100.40	**79.60**	3.88	27.88	**5.64**
130	.1781	.5685	**.8641**	— .560	—29.25	100.75	**79.25**	15.37	21.53	**6.07**

The components c and d were derived directly from the equations and their resultant gave the resultant wind pressure, in magnitude, direction, and point of application (Columns 4, 8 and 11, Table II). Therefore it was possible to plot this resultant wind pressure in its true location and to scale, for the different angles of boom to wind; this is done in Figs. 4 to 15, Plate 8. The maximum resultant pressure occurred at an angle of boom to wind of 110°, which was not unexpected when it is noted that the gaff was then at about 80° with the wind and one might consider that the mean line of the sail was at practically 90°. (All angles were measured upstream from the initial position of the boom.)

The maximum pressure amounted to 0.913 pound for the entire model at 15.1 miles per hour. This corresponds to a pressure of $0.913 \div \frac{148.5}{144} = 0.885$ pound per square foot if we use the net area of the sail (148.5 square inches). It is probably more correct to include the projected area of the boom, mast and gaff and use the total area, which is 148.5 + 2.44 + 5.98 + .89 = 157.8 square inches. This gives for the maximum pressure $0.913 \div \frac{157.8}{144} = 0.833$ pound per

square foot. Eiffel's formula for the resistance of curved surfaces (camber 1 in 7) at 90° with the wind is $0.0033AV^2$ where A is the projected area in square feet and V is the wind velocity in miles per hour. This gives

$$P = 0.0033 \times \frac{157.8}{144} \times \overline{15.1}^2 = 0.825 \text{ pound per square foot}$$

which is an interesting agreement lying well within the accuracy claimed for either experimental work. It would seem that this formula of Eiffel's was applicable to the determination of maximum wind pressure for yachts, provided the area of spars, etc., is included in the area.

The graphical representation of the resultant forces on the sail as shown by Figs. 4 to 15, Plate 8, can be made to give a further analysis of the action, if we apply to it the condition of a phantom boat sailing with different angles of boom to keel line. That is, if the angle between the boom and the wind is maintained constant and a hull is placed at varying angles with the boom, it will then be possible to resolve the resulting pressure into two forces, one at right angles to the keel and the other along the line of the keel. The first does no useful work and produces leeway. The second may be called the *drive* and produces the useful work of overcoming the resistance of the hull and driving the boat ahead. By putting the boat at different angles for a given angle of boom to wind (superposing the diagram of Fig. 16, Plate 8, and turning it to the different angles), the curves of Figs. 17 to 28, Plate 9, are derived. As an analysis of the action of the sails this is probably not as directly useful as one which involves sailing a given course and using different angles of boom to boat corresponding to different trimming of the main sheet.

An analysis along these lines may be obtained by taking cross curves from the curves already derived (Figs. 17 to 28). For instance, if we take a cross curve at 20°, we shall have the effect which the sail produces when the boat is sailing at 20° with the wind and the boom carried at different angles with the center line of the boat. The curves derived in this way are given by Figs. 29 to 40, Plate 10, and all for the constant apparent wind velocity.

It is interesting to consider on what direction of sailing the boat is driven the fastest by this sail. If we assume that the hull resistance is the same for all courses and is not affected by different angles of heel, the course which is at 190° with the wind (Fig. 39) is the one on which the boat will go the fastest. For this course the best angle which the boom should have with the center line of the boat is shown to be about 88°. It should be remembered that this applies to the single sail rig only.

Figs. 41 to 51, Plate 11, show the action which takes place for the different courses, each arranged so that the boom makes the angle with the boat which is most effective for speed, in other words with the main sheet properly trimmed. A very interesting point to be noted here is that, for courses from 45° to 160° with the apparent wind (shown by the fly at the mast head), the angle between the boom and center line of ship for best sailing, with this sail, should be approximately one-half the angle between the fly at the masthead and the center line of the ship.

In all of the work so far considered no distinction has been made between real and apparent wind, but in applying the work to a yacht the wind which is customarily observed is that indicated by the fly at the mast-head. This is the apparent wind, and it is the resultant of the speed of the boat and the true wind. It is obvious that the wind of the tunnel experiments corresponds to the apparent wind. If it is desired to find the relationship between the apparent wind and the real wind or the relationship between the real wind and the courses, an estimate of the speed of the yacht in terms of the speed of the wind must be assumed, and then it will be possible to obtain the direction of the true wind. To illustrate the point, this assumption has been made and the corresponding true wind derived, which is shown by the dotted arrows on Figs. 41 to 51.

A single curve obtained by plotting the maximum points in the curves of Figs. 29 to 40 is given on Plate 12 and may be called the characteristic curve of this sail.

APPENDIX A.*

The wind tunnel of the Massachusetts Institute of Technology was built in accordance with that of the National Physical Laboratory, Teddington, England, with the exception of several changes of an engineering nature introduced with a view to a more economical use of power. An increase of the maximum wind speed from 34 to 40 miles per hour was thus obtained.

Upon completion of the tunnel an investigation was made of the steadiness of flow. It appeared that the variation of velocity with time and from point to point of the cross-section was not more than one per cent.

The wind tunnel proper is a square trunk 16 square feet in section and 53 feet in length (Plate 3). Air is drawn through an entrance nozzle and through the tunnel by a propeller driven by a 10-horse-power motor. Models under test are mounted in the middle of the tunnel on the arm of a delicate balance.

The air entering the mouth passes through a honeycomb made up of a nest of 3-inch metal conduit pipes. This honeycomb has an important effect in straightening out the flow and in preventing swirl.

Passing through the square trunk and past the model under test, the air is drawn past a star-shaped longitudinal baffle into an expanding cone. This cone expands in 11 feet to a diameter of 7 feet. The velocity of the air is reduced in passing through the cone and has its pressure increased in accordance with a well-known hydraulic principle.

The propeller is made of black walnut with four blades (Plate 6). It works at the large end of the cone and discharges into the diffusor. The latter is built of wood grating with holes closely spaced except on the side facing the propeller, which has no openings. The propeller race is stopped by this wall, the velocity of the air destroyed and the pressure raised. The air then escapes through the holes in the diffusor into the room. The current is thus turned through 90° and brought nearly to rest.

The propeller was designed on the Drzwiecki system, which assumes that each blade section is an aeroplane wing moving through the air in a spiral path. In order to keep down turbulence, a very low pitch and a broad blade were used. To gain efficiency the blades were made thin and, therefore, weak. To prevent fluttering of the blades, the blade sections were so arranged that the centers of pressure of all sections lie on a radial line drawn on the face of the blade. This artifice seems to have prevented the howling at high speeds commonly found with thin blades.

The propeller is driven by a "silent" chain from a 10-horse-power inter-pole direct-current motor. The propeller and the motor are mounted on a bracket structure fixed to a concrete block and are hence independent of the alignment of

*Abstract from "Scientific Aeronautical Research," J. C. Hunsaker, Science Conspectus M. I. T., Vol. V, No. 1.

the tunnel. Vibration of the motor or propeller cannot be transmitted to the tunnel as there is no connection.

In order to maintain a steady current of air, the fan must run at constant revolutions per minute, but in order to allow a fine adjustment to obtain and hold any speed, a direct-current motor is necessary. To run a direct-current motor at constant speed requires a steady voltage. Such is not available. Consequently the following procedure was adopted. A 15-horse-power induction motor is connected to the alternating current power mains of the Cambridge Electric Company. This induction motor is coupled directly to a 12-horse-power direct-current generator. The generator supplies current to the motor which turns the propeller. For constant wind speed the load is constant, and hence the induction motor will turn over at constant speed since its slip is a function of load. Variation of voltage in the city mains has small effect on the speed of the induction motor, which runs at a speed proportional to the frequency of the supply current. The generator being turned at constant speed generates constant voltage, and the propeller then runs at constant speed. Due to slow changes in frequency it is necessary to provide variable resistance in the direct-current motor field, by the use of which the wind speed can be corrected from time to time.

Any wind can be made of velocity between 3 and 40 miles per hour.

The model of complete aeroplane, wing, tail, body or other part is mounted on an aerodynamic balance constructed from the plans of the National Physical Laboratory, England. This balance (Plate 5) consists of a cast iron pillar mounted on an independent concrete block, and the balance proper. The latter is made up of three arms mutually at right angles representing the axes of coordinates in space about and along which couples and forces are to be measured. The model is mounted on the upper end of the vertical arm which projects through an oil seal in the bottom of the tunnel.

The entire upper part of the balance rests on a steel point bearing in a steel cone supported by the cast iron pillar.

The balance is normally free to rock about its pivot in any direction. When the wind blows on a model, the components of the force exerted are measured by hanging weights on the two horizontal arms to hold the model in position.

The balance is also free to rotate about a vertical axis through its pivot. The moment producing this rotation is balanced by a calibrated torsion wire.

Special attachments permit the measurement of the force in the vertical axis and moments about the two horizontal axes.

The three forces and three couples acting on any model placed in any attitude to the wind can be studied at leisure. The balance is precise to one per cent.

Velocity is measured by means of a Pitot tube which was calibrated on the whirling arm at Teddington. The Pitot tube pressures are read on a Chattock liquid micro-manometer. Velocity readings are precise to one-half of one per cent.

Tests have been made to determine the lift and resistance of a model aeroplane wing which had previously been tested in England. The results are in excellent

agreement and indicate that the English tunnel and balance have lost none of their precision in the rather extensive alterations that have been made here.

The wind tunnel has been in operation since July, 1914, and has been used for comparison of Pitot tubes, determination of the aerodynamic coefficients for a number of wings, bodies and miscellaneous objects, for thesis work on aeroplone stability and by students in connection with problems arising in the course of aeroplane design.

APPENDIX B.

The method followed in working up the results from the original observations was briefly as follows:

The observed scale pan weights (C_1, C_2, D_1 and D_2) were plotted on angles as abscissæ and the curve faired. (The maximum deviation of any point was about 1½ per cent.) From these faired curves, the differences $C_1 - C_2$ and $D_1 - D_2$ were computed and also faired. The values of c and d were computed, using the values of $C_1 - C_2$ and $D_1 - D_2$ given by the above curves. The values of x and y were computed directly from m, c and d, and are plotted on Plate 6. The values of z were computed from the faired values of the scale pan weights (C_1, C_2, D_1 and D_2) plotted, and Table I gives the results from the curves.

Simple algebraic transformations give the following equations which were the ones directly used for the solution of x, y, d, c and z:—

$$x = \frac{M}{d \tan \theta + c}$$

$$c = 5.625\,(C_1 - C_2)$$

$$d = 5.625\,(D_1 - D_2)$$

$$z = \frac{C_2 l_1 - C_1 l_2}{C_1 - C_2}$$

DISCUSSION.

THE PRESIDENT:—Gentlemen, you have heard the very interesting paper read by Professor Everett, entitled "Aerodynamical Experiments upon a Yacht's Mainsail." The meeting would like to hear any discussion. Some of you, I hope, are prepared to discuss the paper.

MR. WILLIAM GARDNER, *Member*:—I have read over Professor Everett's paper with interest, and I think he is to be congratulated upon being the first one to make a scientific investigation of the principles of sail propulsion. The question of the shape of sails and their form—and by the form I mean the flatness or fullness of the section of the sail—has been a matter of discussion since the early forties. When the America went abroad to race the English boats had full baggy sails, while the America had much flatter sails, but not absolutely flat, and a good many attributed the success of the America as much to her sails as to her hull.

I had the pleasure of seeing Professor Everett making one of his experiments and also of examining very carefully the sail he used. This sail was a model of one that has been successful in practice, and was in keeping with the present idea of the form. The form, which he does not describe in his paper, has a moderate amount of curvature or draft with the greatest amount of curvature forward and the least aft. The aim of the sail-makers at the present time is to get as near a parabolic form as possible. In making his experiments, Professor Everett had a very good example of modern sail making.

The results of his experiments are interesting as the geometrical center of the sail is practically in the same position as the center of pressure, the slight difference, both vertically and in a horizontal direction, being easily accounted for by the windage of the mast. This shows that the draft or form was about right for the wind velocity used, as the pressure must have been even throughout the sail.

A number of questions have been under discussion for a long while. One of them is, as to whether the draft should be the same at all times. Some contend that you should have a moderate draft for heavy winds, a medium draft for medium winds, and a considerable draft for light winds. Others contend that the sail with a moderate draft, but perfectly made, is the best one under all conditions.

I hope Professor Everett will be able to carry on his experiments, or, if he cannot do so, that some one else will take up the work and try, say, three sails with different amounts of draft and try each of these at different wind velocities, so that we will get the further information that we very much need.

This paper is of great value to the naval architect, and of possibly greater value to the practical sailorman. From the data contained a dial could easily be made, having two hands, with two rows of corresponding figures on the circumference. Having set one hand at the angle of apparent wind, the other hand could be set at the corresponding figure. This hand would then give the proper angle of boom for the direction of boat and apparent wind. With such a dial, sail trimming can be brought to an exact science. In the past it has been a matter of judgment and experience.

As I said before, I hope these experiments can be continued, for I feel a complete knowledge of this interesting subject can be obtained.

Mr. Edwin A. Stevens, Jr., *Member:*—I wish to second Mr. Gardner's remarks and words of congratulation to Professor Everett. As there is one point that was not mentioned, I thought it might be well to say something about it, although I hesitate to speak after such a prominent naval architect as Mr. Gardner. About fifteen years ago I had quite some experience in sailing yachts known as the scow type, short water-lines and long, flat ends. This type of boat needs a sail with more draft than the deeper type of yacht, such as are being built now under the universal rule. Not only is more draft needed, but they cannot be sailed as close to the wind, with good results, as deeper bodied boats. It is necessary to ease off the sheets and to make up by footing what you lose in pointing. I have tried trimming the sails flat and pointing up with the deeper bodied boat, and fell hopelessly behind. The minute I eased up on the sheets and pointed off, in some cases as much as a point (especially in light weather, where there is quite a sea), she would make up in footing what I lost in pointing.

The President:—Is anyone else prepared to discuss the paper? If not, the Secretary has some communicated discussion which he will present.

MR. NATHANIEL G. HERRESHOFF, *Member* (Communicated):—I have received Mr. Everett's paper on yacht sails and have read it with a great deal of interest, and am sorry I cannot be at the meeting. There is a great deal to be learned about the driving powers of sails, and I think this paper has opened up the subject in a very good way. I hope such experiments will be continued and include such matters as taking into account the effect of different amounts of bag of draft, for different velocities of wind, the effect of the inclination of the mast, twist of sail, etc.

MR. H. DE B. PARSONS, *Member* (Communicated):—Having read with interest Professor Everett's paper giving results of experiments upon a yacht's mainsail, the speaker is pleased that experiments of this nature are being undertaken.

In the design of a racing yacht, success largely depends on the proper locations of the centers of wind pressure of each sail in order that the vessel may be properly balanced, especially when sailing to windward. So much depends upon the cut of the sails that experiments on one mainsail are probably not sufficient to accurately determine a formula for the location of the true center of pressure. Variations in shape, which result in a flat or loose-fitting sail, and heel of the vessel must necessarily affect the location of the actual center of pressure.

The writer was much interested in the description of the wind tunnel and he takes pleasure in contributing the following information with regard to a wind tunnel which he designed.

In 1913 the writer had occasion to make experiments on the power developed by a new type of wind-mill, known as an air turbine. In order to determine suitable angles for the sails or vanes, the writer designed a testing apparatus, shown on Plate 13, which consisted of a circular, galvanized-iron tunnel, 8 feet in diameter by 38 feet in length. An artificial wind was created through this tunnel by a 96-inch disc fan, driven by an electric motor. By varying the speed of the motor and by changing the size of the pulleys, it was possible to obtain a wide range of air velocities, or wind, through the tunnel.

Baffles were arranged inside the tunnel, located about 8 feet behind the fan, so as to straighten out the flow of air and prevent eddies and swirls. Various forms of baffles were tried, but the one finally adopted consisted of thin wooden vanes, arranged as shown on Plate 13. These baffles worked well and gave satisfactory results, as was proven by tests made with an anemometer and with a delicate pitot tube. Readings with both the anemometer and pitot tube were made at many points in the cross-sectional area of the tunnel, and the readings obtained were consistent and showed a steady breeze.

The model under test was placed near the free end of the tunnel, and air measurements were made in front of the model by a pitot tube, which had been standardized, as mentioned before, by being operated in connection with an anemometer.

The whole apparatus had to be located out of doors. The end at which the fan was located was enclosed by a shed, so as to protect the fan and motor from the weather. The free end of the tunnel entered a chamber, the sides of which were carried up sufficiently high to prevent the natural wind from interfering with the artificial wind created by the fan.

The whole apparatus, as shown on the plate, cost about $1,000 erected and ready for test.

The writer does not offer his design as being better than the one described by Professor Everett, but thought that a record of another wind tunnel, as actually constructed, might be of interest to members of the Society.

Mr. Cornelius A. Wood (Communicated) :—Professor Everett showed me his paper last summer regarding the most efficient ways of trimming sails, etc. The experiments which he performed for these results are very ingenious, and I believe this is the first time that definite information has been collected in a strictly able way on this subject.

For years I have been interested in yachting and have followed it up very closely and in a more or less scientific way. I am convinced that Professor Everett's inductions are not only the result of extremely careful and accurate investigations, but that they are of great theoretical importance in any scientific study of sails, as well as being of considerable interest to the up-to-date racing skipper.

Mr. C. F. Adams (Communicated) :—I received a copy of Professor Everett's very interesting article on sails, and very much regret that it was impossible for me to be in New York to hear the discussion held on it. As we know, sail-trimming is rather a matter of the eye than of mathematics, as a rule, and it is to that extent difficult to say how exactly your results correspond with the usual yachting practice; but I should think no variation is obvious beyond what can easily be accounted for by the absence of a topsail and by the relatively heavy spars which you are compelled to use.

Mr. Charles H. W. Foster (Communicated) :—I received, in due time, the kind invitation to attend a meeting of the Society of Naval Architects and hear Professor Everett's paper discussed. I am very sorry that I shall be unable to be present. I have no doubt there will be much said on that occasion that would interest me extremely.

I have studied the paper and my first feeling is, how much I would like to sit down and talk with the author about it. He has gone just far enough to make us yearn for more in the way of real knowledge as regards a sail. It is astonishing that so little has been done upon the subject which is really worthy of serious consideration.

I note that he has determined the location of the true center of pressure, the normal pressure per unit of area, and the proper angle of boom, all for a given sail. Of course, all these facts are for one sail only, and no consideration is given to the fact that the gaff plays just as much a part in the set of a sail as does the boom. In fact, I think those who are most experienced in boat sailing as a practical matter make more of the trim and tension of their peak halyards than they do of the trim of the boom. It is astonishing what the effect of a slight change in the peak halyard will have in the behavior of a boat. Of course, the effect of this change is not only upon those questions which the author has attempted to analyze, but also affects pressure on the rudder, and in that way the speed.

I do hope Professor Everett will continue his experiments, and to illustrate what is going through my mind in regard to the present experiments I would suggest that he conduct some line of experiments on a sail which is fixed, both as to the gaff and boom and held in the same plane. These experiments should then be followed up by changes in the gaff. I mean by allowing it to swing off more and less than he has done in the present experiment. It would be very interesting to see what happened with his centers of pressure and the amount of pressure. These experiments also would probably show quite a change in the proper position of the boom, or perhaps, I should say, would change the conclusion which he has noted in his present experiments that the boom should be approximately one-half the angle between the apparent wind and the center line of the ship.

In regarding this paper, the layman might not realize that the statements in regard to

the drive or speed of the boat, while scientifically correct, are misleading, if he looks at them from a practical point only. Of course, with the wind say 15 miles an hour, the speed of the boat must be added or deducted from this figure in estimating the real force of the wind, so that the speed of the boat would be quite different from those outlined in Professor Everett's experiment—that is, as the layman sees it.

In actual practice, I once made some quite elaborate experiments and found that on a 21-foot boat the greatest speed was at some six points off the wind. Some time I will show the author the relative speeds on all the different points of sailing as I found them in these experiments.

I hope that he will have continued opportunity to keep on with these sail experiments and will be willing to let me know what he is doing in regard to them. There are many practical questions which experience has suggested to me as being worthy of scientific experimentation, and I would like to feel that somebody was working them out.

Mr. Guy Lowell (Communicated) :—I was most interested in the paper on wind tunnel experiments with the model of a sail, and am sure that the Society of Naval Architects will, too, find it very interesting when it is presented next week. I received the paper on my return to Boston yesterday, and, therefore, can only give a hasty impression of it; I have had no time to compare Professor Everett's results with those of others.

As I wrote the author last fall, I have given a good deal of study to the subject, and the most difficult part has been to determine:

1. What problems we needed to solve aerodynamically in order to study sails.
2. What results had already been obtained by wind tunnel workers.
3. In what way we have had a right to apply the experimental results in a general way to sails.

Since these three questions have been much in my mind during my studies, I must be forgiven if I apply them in reading this paper, and then give my opinion about it.

In the first place, I do not think sufficient emphasis is laid in the paper on the really valuable facts contributed by the author (such as the value of P, at top of page 5, and its relation to Eiffel's surface with a camber of 1/7), and that, *per contra*, too much stress is laid on certain deductions the author seems to have no right to make, or, to be fairer, has no right to lead his reader to make, because in order to simplify his explanations and calculations he quite rightly eliminates certain very real factors; but in applying the results of his experiments to real sailing conditions he in turn neglected to put back those qualifying factors. For instance, the yachtsman knows by experience that the paragraph on page 5, beginning with the sentence, "It is interesting to consider on what direction of sailing the boat is driven the fastest by this sail," is not true.

This is because in actual sailing, such as the author assumes when he makes a practical application of his data to the sailing of a ship, there can be no such thing as a constant apparent wind, which he appears to assume as a condition of his practical problem, for though the real wind is constant in wind tunnel experiments, and may even be assumed to be so on the open water, there is no such thing conceivable as a constant speed of apparent wind when the direction of the course of the boat, and therefore its speed, in relation to a steady real wind, is varying. I enclose the following solution, using Professor Everett's resultant, which shows that a boat can sail faster with wind abeam than with wind aft, as his figures imply.

SPEED BEFORE THE WIND AND WITH WIND ABEAM.

Let us assume:—

1. That your model sail is on a model boat able to sail through the water.

2. That its stability is such that its heel is negligible.

3. That the resultants which are in all cases nearly normal to the planes of reference of the sail are for simplicity of calculations actually so.

4. That the hull resistance is such that an assumed real wind of 15 miles per hour is able to drive the boat "before the wind" at a rate of 7½ miles per hour. (This is a condition I have met in actual sailing.)

Since the real wind is 15 miles per hour the *apparent speed* of the wind when "before the wind" is 15 miles per hour minus 7.5 miles per hour, or 7.5 miles per hour. Now the speed of 7.5 miles per hour equals one-half the real speed of wind, and since pressures vary as the square of speed, the pressure equals $(\frac{1}{2})^2$, or ¼ of 0.913, which is the pressure given in Fig. 14, Plate 8. A speed of 7½ miles per hour is produced by a pressure on the sail of 0.228 pound.

What pressure do we get with wind abeam?

If we solve a right-angled triangle where the hypothenuse represents the speed of the real wind as 15, and another side the speed of the boat as 7.5, the third side representing the direction and speed of the apparent wind which is at right angles to the speed and direction of the boat since we assume wind abeam, we shall find that the apparent speed is ±13 miles per hour.

The diagram for wind abeam (Fig. 9, Plate 8) shows the resultant at 15 miles per hour equals 0.710, but since pressure varies as the square of speed, at 13 miles per hour the pressure equals $0.710 \times (13/15)^2$, or 0.528. But the d ive component in a direction parallel to the keel when the sail makes an angle of 45° with the course, as it does in sailing with wind abeam, is ±0.7 of 0.528 or 0.3696, which obviously is more than the pressure before the wind (0.228).

The course nearly before the wind shown by Fig. 39, Plate 10, is not "the one on which the boat will go the fastest." To find out "on what direction of sailing the ship is driven fastest by a sail," it is not only necessary to have the facts which wind tunnel experiments give us, but we must combine them with data given us by towing tanks experiments, which will give us hull speeds under different pressures, and then the answer will only be correct for the specific hull considered and for a given speed of real wind. That even this last statement of mine eliminates too many factors will follow from my next criticism.

The author seems to imply by his calculations where he combines resultant pressure due to angle that sail makes to the wind with the course that the boat is making with the wind, that what determines the efficiency of a sail is the amount of the pressure or force component parallel to the keel (paragraph 2, page 5). This is not strictly true, because the other component "at right angles to the keel" cannot in practice be overlooked, since it not only "produces leeway" but also produces heel. The efficiency of the sail changes, then, not only with the amount of the keel-parallel component of the resultant, but with the angle the resultant makes with the plane of reference, for in practice Professor Everett's and Eiffel's diagrams show that it is not necessarily normal to that plane. It is a study of changes in the amount, in the direction, and in the point of application of the resultant due to differences in outline (sail plan) of equal areas, and similar changes of the resultant due to differences of curvature for identical sail plans, that will help us most, in my opinion.

The trouble with the whole subject of aerodynamical experiments on sails is that it is new, and, therefore, it is hard to state things clearly. That is what I think Professor Everett needs to look out for in his paper—I don't imply that he has reasoned falsely.

THE PRESIDENT:—I am sure I express the will of the Society if I tender to Professor Everett the thanks of the Society for the very interesting and very able paper that he has read to us.

I am reminded by the Secretary that I neglected to offer to Professor Everett the opportunity of replying to the discussion.

PROFESSOR EVERETT:—I thank you, sir, but I do not think the discussion calls for any comment, except that it has shown that the matter has awakened interest. I will reply later to the communicated discussions.

THE PRESIDENT:—That, may, perhaps, explain my failure to call on Professor Everett, as there was nothing said in the discussion of his paper except in the way of commendations of it, and there was not very much to reply to.

PROFESSOR EVERETT (Communicated):—There has been a surprising unanimity in the comments indicating the desirability of further experiments investigating the effect of fullness or "bag," and that sort of an investigation could readily be undertaken by methods similar to the one outlined in the paper. Such work could be made to also cover the point raised by Mr. Foster, namely, the effect of varying position of gaff with respect to the boom.

Mr. Lowell's comments as to leaving out factors which have a very important bearing in actual sailing is much to the point. A sail is always used in conjunction with a hull and the hull injects factors into the action of the sail which are vital to any complete analysis of its performance. A complete analysis of this sort cannot be made in a wind tunnel and no attempt is made in this paper to connect the sail with any specific hull. For this divorcement of sail from hull it is absolutely necessary in carrying out any experimental work on sails to deal with the apparent wind, as this is the one to which the wind tunnel wind corresponds, as emphasized in the paper.

While it is true that in sailing different courses we do not have constant speed of apparent wind this method of presentation has its simplicity to recommend it. Once we have the resistance curves of the hull from the model tank, the relation between the real and apparent winds becomes determinate, but as this is different for each hull the use of the apparent wind as a prime variable was preferred as it applies to all cases. With this in mind, it is obvious that the statements in the paper which were criticized by Mr. Lowell are, after all, correct, as will be seen by the following further analysis of the example which he cites.

In the first condition Mr. Lowell derives for a real wind of 15 miles per hour and an apparent wind of 7½ miles per hour a resultant pressure along the keel of 0.228 pound. In the second condition he obtains for *apparent* wind of 13 miles per hour the resultant pressure along the keel of 0.3669 pound. These pressures are not comparable unless we increase the speed of the apparent wind of the first condition to that of the second condition, or 13 miles per hour. If this is done, there results for condition one and apparent wind of 13 miles per hour a resultant pressure of $0.228 \times \left(\frac{13}{7.5}\right)^2 = 0.69$ pound, which is in excess of the pressure for the second condition and is the maximum, as stated in the paper.

THE PRESIDENT:—The next paper to be taken up is No. 3, entitled, "Inland Navigation and Barge Construction versus Floating Barges," by Mr. J. H. Bernhard, Associate.

MR. J. H. BERNHARD, *Associate:*—Mr. President and gentlemen, instead of adhering religiously to the paper, I will attempt to show the same thing by the use of lantern slides and some explanation as we go along.

INLAND NAVIGATION AND BARGE CONSTRUCTION VERSUS FLOATING BRIDGES.

By J. H. Bernhard, Esq., Associate.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

In preparing this paper, to be read before this society, composed of representative naval architects and engineers, I have sought for and been unable to find a reason why these very men have been so indifferent to or unfamiliar with the subject as to be unable to build vessels that could economically navigate the interior waters of the United States—interior waters which form in themselves a system far better than in any other country on this globe. Yet one of the first reasons that these very rivers and canals are idle, the reason that the Father of Waters may be watched from the river bank for hours without seeing a boat pass, is undoubtedly the fact that the members of this society—trained, educated, able marine architects—have never put themselves seriously at work to replace the old and obsolete river steamers that ply upon these waters. They have left these problems to laymen, with the result that, while it may be ridiculous for an investor, if he wanted to build a trolley car line, to go to an old-time conductor or street car motorman and take his advice how to build such a line of cars merely because such man was twenty or thirty years in such service, it is apparently not ridiculous for the investor to go to a captain or pilot and ask him how to build a river boat, providing these captains and pilots can show many years of service. In consequence of this we have still plying, upon our inland waters, boats such as are shown in Plate 14.

First of all you are bound to see the great handicaps that are imposed in the nature of the structure of such vessel to economical loading and unloading. The decks of these steamers could very favorably be compared with young forests instead of steamer decks.

An important feature of the old-time river steamers seems to be the amount of smoke they can discharge from their funnels. The more smoke the more pleased is the captain.

Another very important part of successful or unsuccessful navigation, depending upon from what angle you look at it, is the whistle. When I sailed a modern self-propelled barge (such as is shown in Plate 15, contrasted with typical river steamers) up the Mississippi on a round trip of over 4,000 miles, and carried the freight profitably at half the cost of transportation on other steamers, I was severely criticised for putting such a craft upon the river because its whistle could not be heard for several miles.

Finally, one of the best prevailing rules of measuring a successful steamer is by the amount and height of waves it creates. I had to face severe ridicule because this poor boat of mine could carry 1,000 tons of freight at full speed without creating enough waves to rock a rowboat.

The naval architects of this country have turned, and are still turning, their backs to river construction with the result that some of our interior shipyards are splendid antiquarian museums. Oxen may pull the plates from shady trees to the ways, but this does not even impress a casual onlooker with a needed change. It would be really pathetic to describe in detail certain of the interior shipyards of this country that I have visited.

Lately steel construction is slowly but surely replacing wood construction, but the total lack of architects for river craft has brought about an odd situation. Bridge-building companies went into steel barge construction and apparently are holding their own without doing really anything else but building bridges around which they build a watertight hull. In this connection some really amusing facts could be given. For instance, one official of such a company did not want to build a barge for me on my design because he could not see how such barge, not being strong enough to be loaded at one corner with the other corner sticking out in the air, would do, and the very fact that the barges I would build had to be loaded and unloaded with the same care that one would use when loading ocean vessels was proof in this man's eyes that the barge was undesirable. That the Lloyd and American Bureaus of Shipping passed this construction as A1 did not satisfy this American bridge-barge builder. I had the satisfaction of having another official of a similar company prove to me in detail, with careful calculation, how such a barge would buckle up under its own weight, and while listening to his splendid argument in the way of figures there passed in my mind the thousands of "rynaken" plying upon the Dutch Rhine, that acording to his figures would buckle up, but had the audacity to successfully remain in operation and carry freight for generations.

Only recently we had a discussion whether it would be possible to build craft that could successfully navigate the Erie Canal and the Great Lakes on account of the limitation of 15½ feet distance from water level to bridges over the canal. This is undoubtedly very well possible, and I would undertake to build a barge for the New York Barge Canal with a carrying capacity of 2,000 tons, a draught of 10 feet, and fully seaworthy, still being able to carry freight at a cost of ⅞ mill per ton-mile in the canal, and when used in through service at a cost of 1¼ mills per ton-mile.

Another prominent marine expert, after hearing that I had proposed to build a large barge with a speed of 14 miles to navigate the Mississippi, recently made the following remark: "Any fool who can speak of a barge with 14-mile speed on the Mississippi River is no man I want to talk to." I fear that he will seriously attempt to get me removed to some institution for insane when he hears I am now preparing to build a barge with a speed of 24 miles per hour.

The average Mississippi River boats cost $70 per net ton carrying capacity and are of obsolete construction.

"No," the river man objects, "our boats are not obsolete; we have kept pace with the times, and our boats are to-day a great improvement on those of the fifties."

The other day a river captain said to the writer: "You are not familiar with the improvements we have brought about on our river craft; our steamers are now almost fireproof; we have patent tapered floors, balanced rudders, steel and asphalt decks; we have improved tandem-compound or cross-compound piston-valve engine, steam capstan and steering machine, a locomotive type of boiler, wire railings and tiller ropes, electric lights, combined breeching shield and furnace damper, insulated pipe coverings, and many more important improvements that substantiate the statement that our present side and stern-wheel steamers are the best type of boats for river craft in the world."

This enthusiastic description of the important improvements of the present Mississippi River boat, from one of its ardent champions, illustrates better than anything the writer can say their total obsolescence and inefficiency.

This preamble will serve to make clear to you why I believe that navigation upon our rivers is dead because, to some extent, of the fact that you naval architects and marine engineers have permitted the mechanical engineers to steal a march on you by improving their locomotives while you have been blind to one of the largest fields in the entire country for your endeavors—that of our inland waters, the largest of which contains a channel navigable for the entire year, without ice, at a draught of 8 feet for a distance of 1,200 miles.

We must seek, after this war is over, a firm foothold on foreign trade or prepare to face a period of hard times. How could anyone think for a moment of the possibility of seeking and holding foreign trade when lacking efficient methods of transportation at home? The non-use of our rivers, which would permit freight to move at one-fourth of the present rail charges, is a voluntary handicap and penalty which we place on our foreign exports many fold. This war will be decided by the business men of each of these fighting nations upon the markets of foreign commerce and trade. That nation which, while buried under the heavy taxes it must face, can still hold its foreign market—that nation will be the victor in this war, and this is the fact that should earnestly interest us here in this country. This part also affects navigation upon the rivers, and as such directly concerns us, because the sharp competition which will come forth from this war between the victor and the conquered will force upon us an equally severe competition, first to hold our foreign trade and then to hold our home trade. For such competition we must have the highest efficiency at home.

While this country has reduced its rivers and harbors improvements because of the foreign war, Germany, France and Holland have increased their rivers and harbors improvement budget because of the war. We will find these two conclusions, so much in opposition, to be the foundation in time of peace on which we will have to base our fight for the trade of the world.

Being born and raised in a shipyard, coming from a country whose very hold upon the world's trade (its area only 1/250 part the size of the United States, yet the fifth largest customer of this country and equal in its import and export to 70 per cent of the total import and export of this country) was caused and made possible only by its waterways (which are four times larger in miles than its rail mileage)—having lived for many years in various countries and having had the special privilege of living for ten years within the boundaries of the United States, with free liberty to my imagination and energy, I have attempted to understand this problem which I have placed before you.

I therefore first selected, now four years ago, the problem of navigating what I thought the most difficult route in this country. This was from New Orleans to Tuscaloosa, Alabama. First from the Mississippi (at New Orleans), where the very strength of the river accumulates to its maximum, the craft had to enter, through a lock only 40 feet wide, a shallow canal, its entrance diagonal upon the fast Mississippi. This canal was the Lake Borgne Canal, crooked as the Lord of Lower Regions, shallow as a pool, and sufficiently narrow to tempt you to jump across it. From this one suddenly emerges into Lake Borgne, wide, choppy, poorly protected against gulf waves, but even more shallow than the canal. From this through the Mississippi Sound to Grand Pass. This is a pass cut away in hard foundation through a shallow lake about a mile wide and 4 feet deep. In the bottom of this is a conglomeration of clam shells, sand which in the sea water has become as rock, and in this is haphazardly cut a channel with two bends and sharp angles, 600 yards long, 80 feet wide, and 6½ feet deep. Across this is a side current, and the channel is very poorly staked. From there on comes in Mobile Bay, shallow, wide, fairly open to gulf waves. You emerge from this into the Alabama River, and from there to Tombigbee, the Warrior, and Black Warrior. The Black Warrior is a mountainous, diluvial stream running between a range of mountains and so capricious that it has been known to change from a 6-foot river to one 60 feet deep within twenty-four hours. The Warrior is a little more civilized, but still only partly so, and is kept better in tone by means of locks and dams which are very difficult to negotiate. Rarely does one ever see more crooked rivers. At Demopolis it is possible to leave the barge, go to the hotel and have lunch, and walk to the other side of the town just in time to reach the barge which has ever since been moving at eight miles an hour. At another place you can see a spot on the river where you will be within two hours from that moment providing the barge keeps steadily plugging away. The Tombigbee has the characteristics of an alluvial stream, placing overnight sand bars just where you don't expect them. The lower Alabama runs through swamps that may at a slight rise of the river be flooded and look like a lake with the crooked river hidden underneath and with the current never following the river, but running wildly across the meadows, and it it up to you and the boat to find the channel and stay in it. To navigate these routes with a 500-ton tow was considered very difficult, if not next to impossible, unless you were one of the old-timers.

Plates 17 to 24 illustrate the vessels that were built as a result of my efforts.

When they heard that I was building a self-propelled barge of 1,000 tons carrying capacity and, worst of all, with propellers instead of stern wheels, I was ignored, ridiculed, and what not.

I remember distinctly when we came up the river the first time when all navigation had stopped, without any smoke, loud whistle, big waves or the like, how we were looked upon with eyes that plainly told that they did not believe what they saw.

Just above Demopolis is the sharpest bend in the river, which bends at the radius of 365 feet. I had the barge so designed that I felt sure she would turn at a radius of 350 feet at full speed, the barge being 240 feet long and 32 feet wide, propelled by two propellers and controlled by three balanced rudders. When we came to Demopolis we were received by a delegation of citizens who doubted whether we ever could go around Devil's Bend, and I invited them to come along. When I told them that we would attempt to go round the bend at full speed some of the party already on board felt they had better go ashore, feeling safer with the solid ground under their feet. When we came to the bend, plugging away at 8 miles an hour, and attempted to negotiate the bend, the captain, not trusting the barge to the pilot, stood at the wheel himself, and having heard so much about this shallow, sharp bend, overestimated it and turned so quickly that he barely escaped coming on the other side.

These boats have been plying successfully ever since, carrying freight over this route, a distance of 1,050 miles, and returning empty, at a total cost of 40 cents per ton, or about ⅜ mill per ton-mile, one-tenth of the average railroad charge.

In the construction of this boat I departed from the old ideas and placed the cargo on deck, not cutting any hatches in the deck, making the deck like the bottom, airtight and watertight, shut off by watertight bulkheads. Twice these barges, fully loaded, coming downstream at a speed of 14 miles, ran on a boulder, ripping a hole in the bottom several feet square, yet we never had repairs of more than $1,200, notwithstanding that the shipyard was 400 miles away from the nearest accident. Always have the barges been able to go to the yard under their own power, and never have they passed in total accidents over 2 per cent of their insurance value. By placing the cargo on deck I had the advantage of having the entire hold available for strengthening purposes, so that I could place the steel where it would do the most good and have as much as possible the steel members under compression, letting the hydraulic pressure counterbalance the load pressure. The result was that I could use very light material, the hull being built out of ¼-inch plate and frames out of 2½ by 2½ by ¼-inch angle iron. The further result was that the barge, although she carried 1,000 tons net, had only 170 tons of steel in her, and, together with the machinery, bunkers, and the like, a total of 240 tons. These barges displaced 1,240 tons of water, were given a speed of 8 miles per hour with only 150 horse-power, using for this purpose gas-producer

engines burning breeze coke, which brought the cost down to 1/10 cent per horse-power per hour. Plate 16 illustrates the construction of these barges.

From this experience, and the later experience of sending these boats up on the Red River and from New Orleans to St. Paul and back, I have based my decision for the construction of the barges for the Inland Navigation Company, a company recently organized under the State laws of Delaware, capitalized at $9,000,000, and of which I have the pleasure of being president. The barges will be divided into two classes, speedy and slow. The speedy barges will be 310 feet long and 56 feet wide, 9 feet deep, with a draught of 7 feet, propelled by four 600-horse-power engines, estimated to give a speed of 20 miles in slack water—22 miles downstream and 17½ miles upstream. The others, of which the first now nears completion, will be 240 feet long, 42 feet wide, capable of carrying 1,500 tons on a draught of 7 feet, and able to carry 500 tons on a draught of 3½ feet. Plate 21 shows the general arrangement of this type of barge.

The barge is all steel and the hold is divided into five compartments by means of four watertight bulkheads. It is propelled by means of four internal-combustion, fuel-oil, four-cycle, three-cylinder 80 brake horse-power engines built by Fairbanks, Morse & Co., each operating one propeller. The barge is further equipped with duplicate electric power plant, and has absolutely no fire on board, the heating and cooking being done by electricity. It is also equipped with a large number of electric lights and three powerful searchlights, giving a total of 18,000 candle-power, the largest one being of 9,000 candle-power, all pilot-house control.

The bow and stern are each provided with 4-horse-power electric winches; the steering is done by electricity; the pilot-house is completely equipped with all modern appliances, mechanical telegraph, house telephones and spider telephone system, and a navigation telephone system. Two 5-inch centrifugal pumps, electrically operated, can quickly drain the barge and the ballast tanks.

The barge is further equipped with two refrigerating plants, one for the crew, and one for the cargo capable of maintaining a temperature of 35 degrees for a cargo of 6,000 cubic feet. The cargo space is covered by a waterproof steel cargo box, which is straddled by an electric traveling Gantry crane capable of extending a boom outward on either side for a distance of 70 feet and then lift one ton.

Finally, the barge is equipped with a 15-mile launch, a skiff, and life raft.

This brief description of our first barge will give you an idea with what equipment we will attempt to revive inland navigation.

There are, of course, many different problems connected with the success of the Inland Navigation Company, which problems you will find treated in a more detailed manner in an article written by me and published by the American Society of Civil Engineers in their Proceedings of August.

DISCUSSION.

THE PRESIDENT:—This paper of Mr. Bernhard is open for discussion. I would like to ask Mr. Bernhard a question, and that is, what percentage deeper water speed can you maintain with these barges in the canals or shallow water?

MR. J. H. BERNHARD:—We are running practically the whole time in 6 feet of water. There is no part of the channel, except the Mississippi River, where we have 7 feet of water.

THE PRESIDENT:—The hour is so late, I think it would be well not to ask for further discussion at this time, but instead of that to continue the discussion after luncheon. When we adjourn, I suggest we adjourn until two o'clock.

The meeting then adjourned until two o'clock.

SECOND SESSION.

THURSDAY AFTERNOON, NOVEMBER 18, 1915.

President Thompson called the meeting to order at 2:15 o'clock.

THE PRESIDENT:—Is there any one here who proposes to discuss Mr. Bernhard's very interesting paper?

PROFESSOR HERBERT C. SADLER, *Member of Council*:—I think Mr. Bernhard is to be congratulated in bringing this paper before us, on two principal points. The first one is that he draws attention to the development of our inland waterways. We all know that they have been shamefully neglected. Any of us who have been abroad and have seen the development in the continental waterways must be struck with the fact that here we have, in the Mississippi Valley generally, something that is far superior to anything on the Continent, and yet we have done little or nothing to develop it. It is possible that many of our members may know that the Mississippi Valley is capable of supporting probably forty to fifty million people comfortably as regards transportation, development of power, and everything else necessary. Of course it is not altogether the fault of the naval architect or the marine engineer that the Mississippi River has not been developed, or that transportation on that river has not developed. We know that in the early days the railroads practically drove the vessels off the Mississippi entirely. Fortunately we now have an Interstate Commerce Commission, and probably our Mississippi will get back to its own. At any rate, the rate-cutting that went on in the past cannot go on so well in the future, and so I think that we may hope to see some development of the great Mississippi Valley. There is no doubt about the economics of transportation there, and I am sure I personally look forward in the future to a great and large development in that country.

The second point on which Mr. Bernhard is to be congratulated is that he has had the courage of his convictions, that he has gone ahead and tackled these problems of transportation, that he has not been afraid to oppose those high and ultimate authorities, the old Mississippi steamboat men, and has developed a modern type of vessel to do the work necessary under modern conditions.

Some years ago—I will state in order to let Mr. Bernhard know that naval architects have not been asleep all this time—I personally was down in the Mississippi Valley and had the opportunity of meeting some people who were interested in transportation and were thinking of developing a new type of vessel. They were quite enthusiastic about a steam-driven or oil-driven vessel, and I happened to meet the financial men connected with the undertaking, and we went for a trip on the river, I remember. I was talking with one of the men interested in the enterprise, and he finally said to me: "It is all right, Professor, what you say, but yesterday I was talking to one of our old steamboat men, who is a practical man, been on the river all his life, and he told me that the present type of steamer on the Mississippi River is the only practical solution of navigation on the Mississippi." Gentlemen, that banker was so fully convinced that the steamboat man was right that he did not feel inclined to back up this new and modern method of transportation.

That is the kind of thing which has been going on in the Mississippi, and Mr. Bern-

hard mentions it. There has been a good deal of opposition to overcome. You may be aware that some two or three years ago a board was formed to take up this question of transportation on rivers, called the Mississippi Towboat Board. I had the pleasure of being associated with that Board and conducting a number of experiments for them in connection with types of barges. The results of those experiments appear in a government report which, I am sorry to say, is now out of print, but perhaps some time in the near future I may ask to submit the data we obtained there to the Society so that it may be of permanent record. We tested out about nine different types of barges, and those of you who have seen the report will realize the enormous difference that can be obtained by designing a barge properly—that you can save a tremendous amount in the power required to propel the vessel by simply getting the proper design of barge to suit the depth conditions of the river. So that I think this whole problem of river transportation will receive in the future the attention that it deserves.

There is one other item which Mr. Bernhard has touched upon, and which I think is a very important one, and that is the question of terminals. There is no doubt that the economical transportation on our inland rivers cannot take place unless we have proper terminal facilities. The case that he mentions—where he would rather have paid the owner of the lumber than to have carried the lumber because of the delay in loading—illustrates the point, that before we can get really economical transportation in rivers we must have proper terminal facilities.

With regard to the question of driving a thousand-ton barge 24 miles an hour in 6 feet of water, I would rather not hazard an opinion at the present moment.

Mr. Parker H. Kemble, *Member:*—I am glad of the opportunity to express my congratulations to Mr. Bernhard for the results which he has accomplished, because results, after all, always stand and form a monument to the man and his work, and I think also he is to be congratulated on having found financial backing to put his ideas into concrete form.

My excuse for taking the time of my fellow members is that on the 3d of June last I ended in Louisiana an eight months' trip down the Ohio and Mississippi rivers and some of their tributaries, covering between 3,000 and 4,000 miles, which, as time was no particular object, enabled me to spend a large part of that eight months in a study of the conditions of river navigation and the revetment work on these two rivers and some of their tributaries.

There were some points in Mr. Bernhard's paper to which I will take exception, based upon what I saw during that trip.

Beginning with an unimportant feature, mentioned at the bottom of page 19, in regard to smoke discharge, I saw many steamers on the Mississippi, and I rarely saw a steamer smoking except when approaching a landing. I inquired of some of the captains and engineers about this, and I found it was a custom of the good old times when by smoking up in approaching a landing they appeared to be making more speed and more bustle—in other words, it was an advertising feature. The point is that, in the thousand odd miles from Cairo to New Orleans, the many steamers which I saw were not smoking when I saw them, and they were carrying good loads and towing many barges.

On the question of the whistle, from a study of the banks of the Mississippi River, the location of the towns, the roads and the character of the people, they do not have there the "watch your step" or "move quickly" conditions of the east. You will find that the whistle reaching 3 to 5 miles is a great advertising and trade-getting feature. Many of the population do not get up out of bed until they hear the whistle and then have time to get

dressed, get their goods, get down through anywhere from 6 inches to 3 feet of gumbo mud, and be at the levee in ample time to sit there and wait for the boat to arrive. When Mr. Bernhard tries to get hold of way traffic, instead of long distance through freight, I am inclined to think he may find it profitable to put in an auxiliary boiler and a 5-mile stem whistle.

In regard to the middle paragraph on page 20, as to the barges being floating bridges, and the fact that I have rather gathered from the paper that the construction of a vessel so that she has to be loaded carefully and with uniformity is something new, I would say that on the Ohio River I saw not only hundreds but thousands of coal barges which, if you dumped 5 tons of coal in one end and in the other end 500 tons, the sides would open out and the barge would lose courage, and that would be the end of it.

If I remember rightly, at the time of the year that Mr. Bernhard took this barge up to St. Paul, the Mississippi was running about 12 feet over what could be considered normal stream height. Consequently, at the cut-offs there was ample depth of water, ample chance to dodge the side currents, and what is of more importance—on part of his trip, at any rate—the river was falling, so he did not have the question of drift and its effect on his screws to contend with seriously.

As regards new improvements on the river steamers, I think Mr. Bernard has judged these somewhat hastily.

Owing to the lack of terminals and the financial condition of the old packet lines, it has been necessary to nurse along the existing boats, making only improvements that could be done without adding too much to the fixed charges.

There is a large growing trade of local freight transportation, served by boats anywhere from 80 to 140 or 150 feet long, driven by gasoline or kerosene engines, geared to stern wheels, with high economy for the carrying of mixed freight, and which are ahead of anything I have run across on this coast or in the interior—and I might add that, being a Boston man, my sympathies are entirely with eastern waters and a good screw propeller. I went out west with those notions, and from experience obtained in navigating my own boat on those waters, from what I saw in the shape of propeller tugs, from the condition of the waters when the flood is rising and the drift is coming down, and from the further fact that the average river steamer goes ashore once a month, as a matter of habit or custom, I am very strongly inclined to believe that the screw propeller as applied to that form of navigation is a *tour de force,* an engineering feat, and not a commercial desirability. I have seen going down the Ohio stern-wheel steamers that had been aground for six months, with the farmers raising crops around them, only to read in the paper a week afterwards that they had floated off after their exile. That point is mentioned to bring out the fact that when a steamer goes ashore on the rivers she must get off very quickly, there is no time to send for a salvage crew, or she may be interned and remain in captivity for the next three or five months. A screw propeller on a sandbar is not efficient in getting the ship off the bar. You do not need a centrifugal pump forward to push if you have a good reliable stern wheel.

What can be done with an eastern designed stern wheel, with feathering blades, with the experience of the coast to draw on, is a problem, but I do know that in small boats—one of which I have particularly in mind, a small packet that has steel blades and geared engine—the coal cost is about one-third of that on a propeller tug packet running in the same service.

The handling of freight and materials in enclosed rivers, like the Black Warrior, is a different problem from handling it in the Mississippi, particularly in low water. While the

average rate of current which we found on the trip down was only about 2.4 miles an hour, there were plenty of points at which the current ran from 9 to 13 miles an hour, and at low water it is very much of a problem whether, in the narrow, contracted channels, speeds of from 12 or 13 miles an hour up-stream are going to be commercially feasible.

The comparison, as shown in the photographs which we had the pleasure of seeing, is, I think, not quite fair. Had I known that slides were to be used, I should like to have shown you some slides which I have from photographs taken of modern and of existing large Mississippi River freight and passenger boats, which really are those with which this barge should be compared. Some of them do not have the forest of timber shown in these pictures.

One other point, and that is where, on page 23, last paragraph, the author says: "In the construction of this boat I departed from the old ideas and placed the cargo on deck, not cutting any hatches in the deck, making the deck like the bottom, airtight and watertight, shut off by watertight bulkheads."

I saw many steamers on the Ohio and Mississippi rivers. I did not see one that did not embody these features. They are all built that way. It has an additional advantage, that when you strike a snag or run ashore, in shallow water, your machinery does not get wet.

The question of terminal facilities depends greatly on the people and the traffic. I went down south with the usual opinion of the south of a northerner, who has not traveled much in his own country. although I did spend some nine years on the other side, and am reasonably familiar with the ports Mr. Bernhard showed us this morning. I have come back from the south far wiser. The possibilities of the south are wonderful, even to the northerner, but when you consider the mud—such mud as you never dreamed of, mud in some places 60 feet deep, and in others where they do not think they have much mud, and it is 8 or 9 feet deep—when you consider that it is only by continual watchfulness and care that you can keep your river put, so that when you send a letter to a business acquaintance, notifying him that he can deliver freight at the levee, if you do not put a time stamp on it and stay up and watch the bank, you may have to cart the freight 8 or 9 miles in the course of the next three weeks—those conditions have forced the traffic of the Mississippi Valley to the railroads, where they go by inland routes and the traffic can be relied upon. With the increasing stability of the river channels, due to the government work, the country is bound to redevelop in its transportation lines and possibilities; but to my mind the greatest promise of that redevelopment is the growth, the healthy, self-sustaining growth of the local traffic between the various points, which is training the men, developing new types of boats; and as these local connections grow stronger, it will become an easier matter to link them together and get your north and south transportation.

In the remarks which I have made I do not wish anything I have said to be understood as in any way lessening my admiration for the results that Mr. Bernhard has secured. Their object has been merely to emphasize that the features which he has brought to a 1915 perfection are, after all, the features which the nature of the traffic has developed through many years, without the manufacturing facilities or the facilities in material and machinery which the gasoline engine and the steel construction have given him to work with,

Mr. John Reid, *Member:*—I do not want to make my remarks redundant by repeating what has been said by the previous speakers, but I think, touching this problem, Mr. Bernhard has been dealing with things which are not new but he has had to adapt old methods to new conditions; and perhaps my experience may be interesting. I had to do some work in con-

nection with the dredging of the Mississippi some years ago, and I have been interested in the references by the last speaker to the enormous quantity of mud which the Mississippi holds. Engineers were having a large dredge designed to handle 12,000 cubic yards of Mississippi mud an hour, to cost half a million dollars, and when we got the dredge down to the Mississippi River we did not find any mud at all. That is the nature of the Mississippi. If you design for certain conditions, the next week they are different. A flood comes down and takes the mud away and leaves you with sand. Fortunately the mud came back, and we got to work six months afterwards. The Mississippi Valley does not run through a toy country which you can walk across in a day's journey. It is a tremendous territory, and you find, going down the river from St. Louis to New Orleans, or any substantial part of that journey, so many changing conditions regarding climate and mud and sand bars that you cannot lay down the law and say this is the boat or the other fellow's is the boat adapted to use on that river.

I am disposed to take issue with Mr. Bernhard when he throws discredit upon the old Mississippi steamboat captains and engineers when they prefer to stick to their own types. When we are young and active and full of beans we come over to this country—I did it myself—and we go right ahead into everything and tell the people here: "You don't know anything about what you are doing; you are a lot of silly asses. Why don't you do it the way we do it in Europe?" In line with that, I will confess that I went to a contractor who was building several dredges, which cost him more than half a million dollars, and I said: "Your plant is no damned use. I will change it all. Here is a dredge I am building for the Delaware, which will make your plant look like thirty cents." He was affable and pleasant, but did not help me out. He did not say: "Go ahead, and God bless you." He did the opposite. A man must be tactful. You get a lot of antagonism in drawing ahead that way. It is better to work with a man than to antagonize him. I have found in this river navigation business that it is much better to take the man who has spent all his life in work on the river with you as far as you can. Of course, his judgment is not to be relied upon outside of his own line of work, but he does know something about conditions which directly affect the line of work in which he is engaged.

Mr. Bernhard is quite wrong in stating that the naval architects in this country have ignored this river navigation problem. That is a serious mistake to make. They have done nothing of the kind. The naval architect is a man who has a regular line of business, he has a staff in his office to provide for, and he must make a living. Naturally, he goes after the living that is nearest to him, and he is not spending his time walking up and down the banks of the Mississippi River telling the shipping people they do not know what they are talking about. He must have problems stated to him by the shipowner or the navigation man. There is an obligation on him—if he has a new thing, to put it forward to help his client; but wherever there is trade in this country to make business for the naval architect, the naval architect has been a live wire, and you have only to go to the St. Lawrence and the Great Lakes and the canals to see the great trade which has been done in the Lake boats, and to realize how much has been accomplished in the cause of river and canal navigation by the naval architect.

The curious thing is that Mr. Bernhard is only repeating in the Mississippi—and all credit to him—what has already been done in other parts of this country, not only in the type of barge, in the way he constructs it and the methods of propulsion, but in other features—that has all been done before. I have been instrumental in bringing to this country twenty or

thirty river barges, or Canadian canal steamers, or whatever you call them, and we have tried gas engines, and oil engines, have tried various kinds of engines, and we lost a good deal of money trying them. We have done a great deal of experimenting with these things, and if I were able to throw on the screen, just as Mr. Bernhard has done, photographs of the apparatus, you would hardly be able to tell the difference between them and those which Mr. Bernhard has shown you. It is the same type of barge for the same purpose.

As for the terminals and coaling arrangements, those things are not novel, but, of course, credit is due to Mr. Bernhard for having introduced methods of development in a new sphere and a new direction.

There is a remark which Mr. Bernhard makes here which I think is of very great interest to us as naval architects, and that is at the foot of page 20. It is as follows: "Only recently we had a discussion whether it would be possible to build craft that could successfully navigate the Erie Canal and the Great Lakes on account of the limitation of 15½ feet distance from water level to bridges over the canal." Mr. Bernhard thinks they can do that, no difficulty about it whatever, but I think that he has not given this problem as careful study as he has undoubtedly given to the Mississippi problem, because, having looked into it rather particularly, I am quite satisfied that it cannot be done. Of course there is nothing impossible in this country or any other country, if you have enough money to lay out to accomplish the object—you could use aeroplane wings to get over the bridge or you could make a submarine to go down into the depths of the Great Lakes, but what you cannot do is—you cannot design a type suitable for the New York State Barge Canal so that it will be satisfactory for this 15½-foot bridge limitation and the other limitations introduced by narrow sections, and at the same time make that a barge suitable for going through the Great Lakes. The two things cannot be done, but you can get either one or the other. That is important in one way. Here is this great barge canal built at an expense of something like $150,000,000 and it is defective in this, that the type of boat you will put on it will have to discharge its whole load, at terminal points such as Buffalo, into another boat. In other words, half the usefulness of the canal is taken away from it. I have no doubt Mr. Bernhard can provide a boat suitable for taking cargo up and down the canal itself, and probably across Lake Oswego, but when you go into the open lakes the condition is very different—this 15½-foot bridge height holds you down, and you cannot get any decent condition for the pilot house, funnels, etc. When Mr. Bernhard is as familiar with the Great Lakes as he appears to be with the Mississippi, he will realize that what I say is a fact.

THE PRESIDENT:—The Chair wishes to say that having had some experience in navigating southern waters that he wishes to endorse heartily the importance of the subject of low-draught boats shown by Mr. Bernard. There are many thousands of miles of inland rivers which are open to boats which do not draw more than 4 feet of water.

In regard to the comparative value of the stern wheel and propeller type of boat, in my first houseboat I experimented with a stern wheeler. I replaced that houseboat with a boat which had a propeller, and I found the propeller had very many advantages—it was on the whole much more economical and certainly much more agreeable in service.

Is there any further discussion on this paper? If there is no discussion, if the author would like to reply to the comments which have been made, we would like to hear from him again.

MR. BERNHARD (Communicated) :—Referring to the question of President Thompson, let me relate the following experiment.

A self-propelled barge, 200 feet long, 32 feet wide, and at 6 foot draught, attained a speed of 7 miles per hour on Lake Borgne, which has an average depth of between 7 and 8 feet. In the channel, however, from the lighthouse to the entrance of the Lake Borgne Canal, the depth is a little over 10 feet. We had a tug go ahead of the barge at a like speed. The draught of this tug was 5 feet. A rope was tied from the bow of the barge to the stern of the tug, without the tug pulling at the rope—merely keeping it taut. The minute the tug reached the Lake Borgne Canal, which at that time was only 7 feet deep, the rope slackened 40 feet in 200. The minute the barge entered the canal this slackening decreased to a speed of approximately 20 to 25 feet in 200. In other words, the effect of the shallower water channel was more marked upon the tug than upon the barge to the extent of approximately 13 per cent, notwithstanding the fact that the barge drew six-sevenths of the available channel against the tug's five-sevenths.

The remarks of Professor Sadler are very interesting, and I quickly agree with him by stating that the Naval Architects and Mari e Engineers have not so far been the only cause of the decline of navigation upon inland waters. I am rather inclined to believe this is one of the minor causes, but of principal interest when this question is discussed before the Society of Naval Architects and Marine Engineers. There are many reasons of greater importance for the decline of inland navigation and a good deal could be said on this subject—rates, terminals, management, laws, financing, organization, insurance, and many others.

Anyone familiar with the river captain and pilot will agree with Professor Sadler that they do consider themselves the highest and most ultimate authority. As foundation for this they have little more ground than the fact that they have navigated the rivers for a long period. If that would be sufficient justification every old sea captain ought to be one of the best naval architects that could be had.

I seize this opportunity to state that the report as made by the Mississippi Towboat Board, to which Professor Sadler refers, is highly instructive and interesting and contains a mass of very valuable data, and said report should be on the desk of anyone connected in a responsible way with inland navigation.

I would doubt with Professor Sadler the wisdom of driving a 1000-ton barge at a speed of 24 miles an hour through a channel 6 feet deep, but this has not been nor is it now my desire. I think for such speed a greater depth of channel is required—certainly not less in average than 12 feet against a draught of 7 feet, and we may safely say that the average depth of channel between St. Louis and New Orleans is certainly not less than 12 feet, although of course over the bars there may be as little as 9 feet, or perhaps in some cases 8 feet of water.

The remarks of Mr. Kemble are indeed very instructive and I regret exceedingly not having had the pleasure of meeting this member of the Society.

The experience Mr. Kemble had with the smoke discharge of the average river steamboat is slightly different from my own, and I think I could convince Mr. Kemble with the correctness of my statement by taking him on the decks of any river steamer. The cracking of the s ot under his feet would quickly impress him that I am not so wrong after all. I do admit gladly, however, that of late this affair, which is after all of minor importance, has received better attention.

I cannot agree with him about the wisdom of these big whistles but gladly grant him his point, although I can assure him it will be a very long time before there is an auxiliary

boiler to supply the steam for the whistle on any boat for which I am responsible. I would then rather follow Mark Twain's prescription, namely, stopping the boat to blow the whistle.

I believe Mr. Kemble has made a very unfortunate comparison between the tow barge and the self-propelled barge. I would not for a moment care to make such comparison. What I did compare was the unit of the self-propelled barge system against the tow system. As part of the tow system there are, for instance, the coal barges, some of them called "cracker-boxes," but to compare these barges with the self-propelled barges seems like comparing a push-cart with a motor truck. In matter of strength I compare the self-propelled barge to the sternwheeler, or steel barges as built by the American Bridge Co. and the like, which, in my opinion, exceed by far the strength that would be required of them if they were handled with the proper care.

I cannot agree with Mr. Kemble either when he states that, when I sent in August of last year a barge from New Orleans to St. Paul, we had 12 feet over what would be considered normal stream height. As a matter of fact we had in many cases less than 5 feet in the channel, and had to do a good deal of hunting to find the channel at that. Our carrying capacity was greatly restricted on account of the very low water.

Where Mr. Kemble says his sympathies are entirely with the screw propeller, I would like to answer that my sympathies are with no particular method of propulsion but merely with the best method under each circumstance. I do believe there are cases when the sternwheeler is best, as, for instance, shown when I advocated the construction of the old type sternwheeler with steam engines and boilers on the Peace River. I for one do not believe any judgment should be passed on any type of inland craft unless one is familiar with all the details—the route, channel, freight to be handled, distance to be covered, and many others. The fact I wanted to make clear is that this blind following of the sternwheeler on all our waters is not correct.

His remarks about the screw would perhaps not have been made had he been familiar with the amount of driftwood the self-propelled barges have had to contend with for over two years. The changing of the propeller blade or propeller will eventually mean nothing more in time loss than the changing of a tire on an automobile, and this efficiency once established will certainly give added reasons against the sternwheel which lifts, on steamers now running between New Orleans and St. Louis, often as much as 50,000,000 gallon-feet of water needlessly.

As to the chances of getting a screw-propelled barge off a sand-bar against that of a sternwheeler, I can assure Mr. Kemble that under many circumstances I would rather have a screw-propelled barge there than a sternwheeler. I think I would be able to quickly convince him should he be on a multiple screw-propelled barge when grounded.

When Mr. Kemble says there are plenty of points on the Mississippi River where the current runs up to 13 miles per hour he must be mistaken, and I doubt if he could point out one place on the Mississippi, from St. Paul to its mouth, where the average current exceeds 6 miles. There are two places where the current may exceed a speed of 8 miles on very rare occasions, but I doubt this.

When Mr. Kemble referred to my statement that the cargo is carried on deck without any hatches he replied that he has not seen any steamers on the Ohio that did not embody these features. I think he must be mistaken. I frankly admit I do not know of a sternwheel boat on any of the inland waters that has not some opening in the deck and which decks are watertight.

I do think that his statements about mud and changing of a bank 9 miles in three weeks is rather ludicrous. As to the change and stability of channels I suggest that he reads page 109 of the report of the Chamber of Commerce of Rotterdam of 1913, which says a few words about the change of the channel in the Rhine which will put his statements to shame.

I can agree with few of the statements made by Mr. Reid. Let me assure Mr. Reid I am not one of those foreigners who thought to revolutionize America the day after his landing. Most of what I have learned was learned here in the United States, and I look upon this country as a most kind employer and teacher. I have merely attempted to repay my gratitude in doing my best, analyzing problems in my profession as I saw them, the privilege of an engineer, not the rights of a foreigner. I at least have never been one of those men, like Mr. Reid confesses to have been, who stated that the people on this side were a lot of "silly asses," and I do not like to see Mr. Reid attribute such ideas to me, and will gladly grant him all the credit due to his statement that he claims. When he told the contractor that his plant was no "damned use," I would suggest that Mr. Reid, if he is a foreigner like I am, had better study local conditions before he again makes such a statement. It has taken me many a year—almost ten now—of hard study before I was ready to condemn what I believe as an engineer to be wrong. No wonder Mr. Reid got a lot of antagonism, from which I have been able so far to steer clear to a great extent.

Mr. Reid further takes issue with me and states that I am entirely wrong when claiming that the naval architects of this country ignore river navigation problems. A careful reading of his next eight sentences prove to a great extent, if not entirely, my statement, which, however, was not as strong as Mr. Reid put it. I have said neglected—not ignored.

I am glad to see that Mr. Reid winds up by stating that after all I am copying what he has done before, only, according to his statement, "lost a good deal of money trying it," and thus was not so successful as I.

Mr. Reid further seems to doubt the possibility of building a boat which will navigate the New York State Canal and the Great Lakes. It is his privilege to doubt this, only doubting Thomases have not so far moved the world. It may be of interest to him to know that money has been set aside to permit me to carry out my plans, which seems to show that money (naturally timid) is willing to agree with me.

I wish to thank the Society for the opportunity afforded me in laying the matter before them, and I wish to repeat that the only desire I have had in reading this paper is again calling attention to the great inland water systems of this country and to impress the naval architects of the United States that a great opportunity and large rewards are waiting for those who care to devote a portion of their time and intellect to the solving of their problems. I will be the last man to claim I have solved all or any of these problems, but I do claim the fact that I am earnestly devoting the best that is in me toward understanding the difficulties confronting us, and if I can be in this manner of some service to this great country I shall consider myself particularly blessed.

Mr. Parker H. Kemble, *Member* (Communicated) :—I have read with much interest Mr. Bernhard's criticism of my discussion on his very valuable paper, and would comment briefly on one or two points.

As regards smoke—it is to be noted with interest that the photograph on Plate 14, supplied by Mr. Bernhard as an illustration of the "Typical Stern-Wheel River Steamer," shows absolutely clean stacks although the boat is traveling at good speed.

As regards soot—although this introduces a new topic, as the original paper and my discussion refer only to smoke, I will say that I have found fully as much soot and cinders on the decks of our Atlantic coastwise vessels as on the decks of the river steamers, and I do not think that even Mr. Bernhard will venture to maintain that our seagoing vessels are absolutely out of date.

As regards my "very unfortunate comparison between the tow barge and the self-propelled barge" and his "I would not for a moment care to make such a comparison"—if Mr. Bernhard will read his own paper he will find in the paragraph under discussion (page 20, par. 3) that he compared the tow barge built by the American Bridge Company with his own barge, so I am only following in his footsteps.

As regards the speed of current—I have before me a government report which gives, under the heading of "Currents Mississippi River," a table of mean cross-sectional velocities for each month of the year. For February, near Fort St. Phillip below New Orleans, 6.5 knots is given. It also adds:—"The greatest velocity in a given section is generally about one and one-third times as great as the cross-sectional velocity."

If this be reduced to statute miles, this gives a speed of 10 miles an hour. In some of the reaches of the river nearer Cairo, this current velocity is at times materially exceeded, particularly near cut-offs on a rising river.

With regard to the carrying of cargo on deck—if he will refer to the paragraph on this subject in his paper he will notice that he particularly emphasizes that "I departed from the old ideas and placed the cargo on deck;" and further along in the same paragraph that "by placing the cargo on deck I had the advantage, etc. * * *" My point was and is that all of the river steamers carry their cargo on deck and have so carried it for many years.

With regard to the changing channels I would suggest that a study of the reports of the U. S. Army Engineers would be more illuminating to Mr. Bernhard as to what the Mississippi has done and is doing, than a study of the reports of the Chamber of Commerce of Rotterdam, on "the change of the channel in the Rhine." Also, the next time he is going up the Mississippi, if he will spend a half-hour examining the conditions at Point Pleasant Reach, he will see the river preparing for a cut-off, which, if not checked by the government, will cut off twenty odd miles of channel and leave New Madrid nine miles inland.

Plate 25 shows a typical stern-wheel river steamer with the slight haze at the stack, which shows good firing. The plate also shows the cargo all on deck and a construction which requires careful loading and unloading in order not to destroy the structure—both points for which, according to his paper, Mr. Bernhard claims original credit.

THE PRESIDENT:—We will now pass to Paper No. 4, entitled, "Variation of Frictional Resistance of Ships with Condition of Wetted Surface," by Naval Constructor William McEntee, U. S. N., Member. In the absence of Mr. McEntee, the paper will be presented by Naval Constructor Joseph H. Linnard, U. S. N., Retired.

Naval Constructor Linnard presented the paper.

VARIATION OF FRICTIONAL RESISTANCE OF SHIPS WITH CONDITION OF WETTED SURFACE.

By Naval Constructor William McEntee, U. S. Navy, Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

Considering that frictional resistance is the most important element in the resistance of practically all ships, it is noteworthy that investigations of conditions affecting it have been relatively few. Although there have been many attempts made to reduce this resistance by different methods and there are many references made to its increase from fouling, there appear to be relatively little actual data as to the quantitative variations obtained.

The results here given are based on a series of tests made at the United States Experimental Model Basin during a period extending somewhat over a year. The investigation was begun by Chief Constructor D. W. Taylor, U. S. Navy, before he gave up the immediate direction of the Model Basin work as a result of his appointment as Chief of the Bureau of Construction and Repair in the Navy Department. The writer therefore thanks him for permission to use the data given in the present paper.

The coefficients of friction for different kinds of ordinary surfaces, and for variation in length of surface, were determined, as is well known, in experiments made by William Froude years ago, and subsequently confirmed by other experimenters. These are the coefficients used in estimating the frictional resistance of a new ship with clean, well-painted bottom. When, however, the condition of the bottom changes, the resistance changes, and the extent of this change is a matter of prime interest.

In considering this general subject, two queries naturally arise:—(1) On actual ships, what is the increase in resistance due to fouling? (2) Is it possible to reduce the frictional resistance by modifications in the condition of the frictional surface, or by the application of materials which would tend to make the surface smoother?

EFFECT OF FOULING.

The method adopted to investigate this subject was to expose to fouling in sea water twelve 10-pound steel plates 2 feet wide by 10 feet long, painted with two coats of anti-corrosive paint. The plates were placed in the water July 10, 1914, at a point in the Chesapeake Bay near the navy yard, Norfolk, Va., where the water ordinarily has a density of 1.02; that is, contains about 75 per cent as much salt as is ordinarily found in sea water.

The plates were removed from the water at intervals of one month, carefully packed so as not to remove any of the fouling, which consisted mostly of small barnacles, and shipped to the Model Basin, where they were tested to obtain the frictional resistance. The appearance of three of the plates removed from the water at the end of three, seven and twelve months, respectively, is shown on Plate 29.

Each plate as received at the Model Basin was tested at speeds ranging from 1½ knots to 8 or 9 knots, and gave results which are shown typically for one plate on Plate 26. After this the plate was carefully cleaned, scraped and repainted with a coat of Norfolk anti-fouling paint and retested at the same range of speeds as when fouled, and the coefficient and exponent for the clean condition determined. The fouling matter removed from the plates was weighed so as to give a measure of the amount of fouling. The weights given by the dotted line on Plate 27 are for this fouling matter when dry.

On Plate 27 is shown the resistance of the fouled plate at 10 knots as a percentage of the resistance of the same plate when cleaned and painted. These resistances are plotted on the time during which the plate has been exposed to fouling.

In Table I the data obtained at different speeds are given in tabular form.

It will be seen that the maximum increase is such that the resistance when foul is four times as great as when the plate is clean and freshly painted.

Referring to Table I it will be seen that not only does the coefficient of friction increase greatly but that the exponent in the formula, $R = SfV^n$, also increases and has a value averaging about 2.00 as compared with the value of about 1.88 for the clean plates.

These results indicate the importance of keeping a vessel's bottom clean and well painted, though it is not considered that the relative effect on a ship's resistance due to an equal amount of fouling would actually be as great as that obtained in these experiments, as it seems probable that the decrease in frictional coefficient due to increase of length would be relatively greater for the foul condition than is found to be the case for clean, smooth surfaces.

EFFECT OF LUBRICATION.

At various times attempts have been made to reduce the frictional resistance of ships by lubricating the under-water surface or by polishing it to a high degree of polish with various materials. One favored method used for racing yachts is to polish the bottom with black lead or graphite. An investigation of the benefits to be expected from such polishing or lubrication has recently been made at the Model Basin with friction planes of the dimensions shown on Plate 28. The two planes used were those with which the frictional coefficients of several ship bottom paints were determined a few years ago. These planes are roughly 20 feet by 2 feet by ¾ inch, with ends sloped forward at an angle of about 30 degrees. Total wetted surface for each is about 82 square feet.

The planes were sandpapered smooth and coated with shellac, and in this condition were each towed in the water at speeds ranging from 1 to 11 knots.

One plane was next coated with black lead or graphite, which was mixed in sour milk and applied with a brush to the shellacked surface of the plane. When dry, the lead was rubbed down to a fine, smooth polish. Ten runs were made with this plane at speeds from 5.1 to 6.5 knots. The graphite seemed to cling well to the surface and showed no abrasion or wear. When wet, however, it was easily rubbed off.

The next material tried was ordinary Ivory soap, which was mixed as a thick emulsion in water and applied with a brush. The plane was run at speeds from 6 to 9 knots. The soap left a whitish streak in the water the first run, but not thereafter. The resistances obtained on all of the runs were consistent, so that the quality of the surface was probably unchanged during the course of the experiments.

Two other lubricating materials experimented with were heavy cylinder oil and light cylinder oil. The oil was applied to the shellacked surface of the plane when dry with a brush, the plane being suspended over the position in which it was attached to the towing carriage, so that it could be run in the water as quickly as possible after the application of the oil. The plane with the heavy engine oil was run at speeds from 6 to 8½ knots. The observations obtained were consistent, but the slope of the resistance line when plotted on log paper indicated that at speeds of about 3 knots the frictional resistance would fall below that of the smooth, shellacked surface. This peculiarity is possibly due to the fact that parts of the oil formed in drops or globules and wavelets, increasing as the speed increased, thus changing the condition of the surface which might, if tested at lower speeds, not have given results lower than shellac.

The experiments with the light engine oil indicated that for the first two runs the resistance was a small percentage greater than for the shellacked surface. Apparently as the oil was washed off the resistance decreased until the resistance agreed with that previously obtained with shellac.

The results of the experiments indicate that no advantage over a smooth varnish or shellacked surface is obtainable with the materials used. For each lubricated surface the resistance is greater than for the shellacked surface. The resistance increases in the following order:—Black lead, light engine oil, Ivory soap, heavy cylinder oil.

The gross resistances for the different surfaces, with actual observed spots as plotted on logarithmic paper, are shown on Plate 28.

The lubricated surfaces were tried only over a limited range of speeds, from 6 to 9 knots, as it was thought that the exponent in the formula $R = SfV^n$ could not be used, owing to the changing condition of the surface due to the washing off of the lubricating material. Actually it was found, however, that the light engine oil was the only material for which the resistance changed rapidly, and that washed off quickly so that the resistance came down to that for shellac.

In Table II is given a tabular comparison of the results.

TABLE I.—*Showing Increase in Resistances of Plates when Foul as Compared with the Same Plates Cleaned and Freshly Painted.*

Months in water.	Increase in resistance in lbs.											
Speed knots.	1	2	3	4	5	6	7	8		10	11	12
2.....	0.24	0.40	1.17	2.09	2.50	2.52	2.80	2.76	2.61	2.97	3.09	3.36
3.....	0.72	0.88	2.83	4.94	5.79	5.72	6.45	6.31	6.17	6.93	7.28	7.78
4.....	1.48	1.56	5.19	9.09	10.53	10.22	11.79	11.38	11.02	12.75	13.39	14.20
5.....	2.55	2.45	8.41	14.59	16.71	16.08	18.55	18.03	17.32	20.30	21.40	22,50
6.....	4.02	3.54	12.42	21.40	24.32	23.20	27.20	26.16	25.13	29.83	32.43	33.07
7.....	6.77	4.74	17.35	29.60	33.45	31.70	37.00	35.95	34.23	41.15	43.4	44.65
8.....	7.82	6.20	22.90	....	44.20	41.60	48.65	47.50	44.80	54.50	56.8	60.10
9.....	10.40	7.75	29.40	....	56.35	52.85	....	....	56.95	69.85	....	....
10.....	.....	....	....	....	....	....	.....	....	....	....	....	....
Coef. foul plate ...	0.01138	0.01282	0.01667	0.0239	.0255	.0252	.02745	.02666	.0275	.0285	.0273	.0292
Exp. foul plate	1.994	1.928	2.029	2.002	2.003	1.988	2.000	2.000	1.967	2.015	2.055	2.035
Coef. painted plate	0.01071	0.01004	0.01000	0.01189	.0108	.0095	.0108	0.01013	.01075	.00903	.0096	.0095
Exp. painted plate.	1.869	1.918	1.937	1.855	1.874	1.938	1.880	1.912	1.869	1.848	1.914	1.924

Coef. = Coefficient. Exp. = Exponent in formula $R = Sf v^n$.

TABLE II.

Surface.	Plane.	Area, sq. ft.	Coef. of friction.	Exponent.	Net resistance at 7 knots in lbs.	Percentage increase in resistance at 7 knots.
Shellac	AB	82.12	.00878	1.883	28.1	....
Shellac	CD	82.20	.00849	1.886	27.4	....
Black lead	CD	82.20	.00866	1.886	27.9	2
Light engine oil.....	AB	82.12	.....	.....	28.3	5*
Ivory soap.....	AB	82.12	.01045	1.898	34.5	23
Heavy cylinder oil.....	CD	82.20	.00484†	2.38†	40.5	48

*At 6 knots.

†This low coefficient of resistance is combined with a high velocity exponent and probably would become greater at speeds lower than those at which experiments were made.

DISCUSSION.

THE PRESIDENT:—Gentlemen, you have heard this paper on "The Variation in Frictional Resistance of Ships with Condition of Wetted Surface," by Naval Constructor William McEntee. Is there any discussion of the paper?

SIR ARCHIBALD DENNY, *Member* (Communicated):—That fouling of the nature and extent dealt with in this paper has a most prejudicial effect is not surprising, but we have found here that fouling which does not exhibit any visible growth is also prejudicial. After launching, the vessels lie in brackish water in our fitting-out basin, and it is our practice, as often as possible, to run a preliminary trial before docking, and a complete set of progressive trials after docking, when we frequently get an increase in speed of half or even of three-quarters of a knot.

Examining the bottom in dock we find no apparent fouling; indeed the surface seems exceedingly smooth and even slippery. By repeated comparisons before and after docking we have got a figure for the effect of this fouling, namely, that for each day a vessel lies in our dock the skin friction resistance increases at the rate of nearly ½ per cent per day, and this we have found to be true for periods as long as three months. It would be interesting if similar experiments could be made in other districts, as, although we have no definite evidence of it, we have reason to believe that the kind of fouling that takes place in Glasgow harbor disappears when the vessel reaches salt water. The Glasgow harbor is only 16 miles up the river Clyde from here, but our yard is on the river Leven—a tributary to the Clyde, and it may be that the water of the river Leven causes a different kind of growth.

NAVAL CONSTRUCTOR MCENTEE (Communicated):—The statement of Sir Archibald Denny with regard to the experience of his firm in the increase of frictional resistance of

ships is extremely interesting. From the tests made as reported in the present paper it appears that the average increase on the plates is about four times that reported in Glasgow harbor; in other words, it is about 2 per cent per day. As stated in remarks in the paper, the extension of these results to full-sized ships would require an allowance to be made for the change in coefficient and exponent due to length, and this is a matter which it is hoped may be determined in future investigations. The statement with regard to there being no apparent reason for the increase in fouling, in that the surface of the vessel seems exceedingly smooth and even slippery, is also confirmed by the experiments made at the Experimental Model Basin, in which it is shown that surfaces which have been oiled or coated with soap have more resistance than the plain, hard-varnished surface. It must be confessed that this result is contrary to that which might naturally be expected from *a priori* reasoning. If arrangements could be made to run a trial trip of a vessel at equal intervals, say of two months, over a period of a year, it might be possible to get further light on this interesting and important subject.

THE PRESIDENT:—We will now take up Paper No. 2, entitled "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Mr. Elmer A. Sperry, Member.

Mr. Sperry presented the paper.

RECENT PROGRESS WITH THE ACTIVE TYPE OF GYRO-STABILIZER FOR SHIPS.

By Elmer A. Sperry, Esq., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

It was due to the desire on the part of the officers of our navy to obtain reliable data at first hand that certain noteworthy experiments on board the U. S. S. Worden with the active type of gyro-stabilizer were undertaken. The gyros were fitted to her main deck solely for experimental purposes and for obtaining very complete data and records having an important bearing on the question of stabilization. The observations thus made were quite diversified as they were made to include the stabilizer plant proper, all the features of automatic precession control, methods of producing artificial precession of the gyros, and also observations on the ship itself under conditions of stabilization as to motion and behavior and also the effect upon the structure. As a result of this work it has been established that the gyroscope is useful in solving certain problems at sea, and orders have been issued for fitting permanent plants, thus putting it into practical service.

Since this work further investigations have been in progress. Among these have been determinations of the exact amount of the true wave increment the gyros are required to neutralize, involving the relation of the gyro-quenching increment to the natural extension curve of roll of the ship. Some of this data was touched upon in the paper presented to this society in December, 1913.

Since this time further experience has been obtained and a number of experiments have been undertaken to determine the relation of ship to gyro. It is gratifying to note that all of this work has proven the soundness of the basic formula originally laid down by Naval Constructor Taylor, now Chief of the Bureau of Construction and Repair of our navy, in course of which he points out that gyro moment of stabilizer equipment for ships varies directly as the characteristic of the ship; *i. e.*, the product of the displacement, the metacentric height and period of roll. There is no variation from this rule involved in the fact that it has been definitely ascertained that small boats require relatively larger moments or greater stabilizing power than is the case with larger ships. This means that waves of given magnitude beleaguer small ships more than they do large ones, which is to be expected, and therefore require relatively more roll quenching power to be fitted. Again, it is possible to adjust the plant in other ways to meet special conditions such, for instance, as limited space, met with in the case of submarines; limited weight, which is the case where the gyro is placed on deck, as in the motor yacht Widgeon, and which

is also the case with submarines; then again the condition where a limited power supply is available for spinning the gyro or gyros and handling the equipment.

Inasmuch as the roll quenching power of the gyroscope varies as the square of its diameter and only directly as its speed and weight, and inasmuch as another factor, *i. e.*, the power required for spin at the higher rates, varies almost directly as the cube of the peripheral velocity, it will at once be seen that where ample space is available and the matter of weight is not critical the rotor and spread of bearings may be so adjusted as to require a minimum of power for maintaining the spin of the wheel for a maximum of gyroscopic moment; and vice versa where only a limited space and weight are permissible and an abundance of power available, a small gyro spinning at higher velocity may be utilized for developing comparatively large stabilizing moments.

As is characteristic of western enterprises, it has come to pass that the first commercial gyroscope stabilizing equipment to be installed has been placed upon the beautiful little yacht Widgeon plying on the Great Lakes, owned by Mr. H. M. Hanna, Jr., of Cleveland, Ohio. This was placed in service in the autumn of 1915, and is of the full active type. The characteristics of the Widgeon, after some investigation, were determined to be as follows:—

Displacement	165 tons
Metacentric height	1.75 ft.
Period of roll, over and back	4.75 sec.
Water line length	120 ft.
Water line beam	18 ft. 2 inches
Total submerged amidship section	80 sq. ft.

For this ship a gyro was selected giving a K^2W 2,700 lbs.-ft.^{2}, 2,750 revolutions per minute, roll quenching power per increment, 5°, the gyro rotor, shaft and armature weighing 2,150 pounds.

The space selected as best suitable under all conditions for the location of the plant was on deck just abaft the stack, where it has been surrounded by a cabin-like housing (shown in process of building in Fig. 1, Plate 30), conforming with the superstructure of the yacht, provided with windows permitting full observation of all of the movements and oscillations of the gyro, which are known to be more or less unusual and interesting in character. The total weight of the equipment is about 1 per cent of the displacement.

This yacht was looked upon as being a very free roller and has been reported to have rolled through an arc of 70° or thereabouts. The gyroscopic roll recorder (see Fig. 18, Plate 36) afterwards employed in this ship showed, however, that the estimate of roll from the ship's clinometer may have exaggerated this arc to some extent. After installation it was found that when the gyro was thrown "off" a free roll of from 24 to 40° of total arc was quickly developed while running in the trough of the sea, and when the gyro was thrown "on" this was quickly reduced and held at 2 or 3°.

From the characteristics of the Widgeon the position selected and the fact that a little gasoline-electric generator installed for the purpose was available for driving the gyro, a wheel of 3 feet diameter by 10 inch face was adopted as the size best suited to the conditions. This wheel, shown in Fig. 2, Plate 30, is run at very low fiber stress, giving a very large factor of safety, the maximum stress being about 12,000 pounds. The current supply being direct current, a direct-current motor was constructed practically as a part of the rotor shaft, as is shown in Fig. 3, Plate 30.

In reviewing this figure it is interesting to note how small a motor is really required to maintain such a wheel as this at a speed of about 2,750 revolutions per minute, this motor having run the wheel repeatedly to 3,500 for over-stressing and test purposes, the motor shown being in excess of the actual spinning requirements by fully 300 per cent for quickly energizing the mass in getting up to speed.

At the ends of the shaft are located the main bearings which, though specially made, are the ordinary annular ball type, ample provision being made for taking care of the end thrust. In each end of the casing there are oil wells and a little slowly rotating oil pump which circulates the oil upwardly through the coolers, a strainer seen in Fig. 4, Plate 31, and back over the top of the bearings, thus insuring both ample lubrication and cooling of the bearings. The temperature difference between the incoming and outgoing oil is just noticeable when the gyro is doing full duty in heavy weather, this temperature practically equalizing when the gyro is not precessing.

It is interesting to note that while the radial load on these bearings varies between practically zero and about 6 tons, the power varies only slightly—one observation showed a change of from 35 to 40 amperes only between these two conditions. This indicates that the power consumption is due in small degree only to the bearings, be they loaded or otherwise, but largely to windage, which is constant for constant speed, which was maintained in these tests.

The system of control is practically identical with that which was finally adopted in the last experiments on the Worden, that is, a small auxiliary gyro, shown in Fig. 5, Plate 31, is employed to feel out the incipient rolling of the ship by closing small electrical contacts plainly to be seen, as soon as the ship rolls very slightly one way or the other. These contacts are required to handle only a very few watts, in fact about one-quarter of the energy of an ordinary incandescent lamp, and through a relay switch serve to actuate a small reversing motor which constitutes the precession motor shown in Fig. 6, Plate 32. This motor precesses the gyro upon its main supporting gudgeons at the ends of the frame; it is here that the gyro lays hold upon the ship to control its movements.

To follow the motion of the precession motor, it is transmitted through a centrally located flexible coupling on the periphery of which is seen the solenoid-controlled brake, which always goes "on" when the motor is "off," and vice versa. The coupling drives a worm engaging a worm gear within the oil-tight housing to the left in the figure (Fig. 5). The steel pinion seen in the foreground at the end

of the worm gear shaft engages the circular rack upon the precession frame, shown in Fig. 7, Plate 32, so whenever the motor turns in either direction the precession frame slowly tilts or oscillates to and fro upon its main gudgeons. The response to slight angles in the ship's motion is found to be very complete—one person walking from rail to rail actuates it—and practically without time lag. With each of these tilts of the gyro very heavy gyroscopic moments are developed and delivered to the ship simultaneously with and in opposition to each wave increment from the sea; these opposite forces cancel each other and, while this contest of forces goes forward, the ship, with its ponderous mass which always requires time to take on motion, stands aloof and does not move one way or the other until one of these forces conquers. The gyro is always victorious and the ship is thus actually given an incipient roll in the opposite direction and the contact of the little controlling gyro which initiated all of these movements is finally broken, the precession motor stops, the brake is applied and the generator of heavy opposing gyro moments in that particular direction is brought to an end. The gyroscope itself is thus free and stands ready to neutralize and quench the next wave increment or rolling increment which usually arrives from the opposite side of the ship, whereupon the above cycle of operations causes the gyro to automatically oscillate oppositely and effectually prevents any roll beginning in the opposite direction.

Inasmuch as all rolling of ships is due to an accumulation of individual wave increments, and since each increment is checked and neutralized, as we have seen, the ship never starts to roll and therefore never rolls.

The plant works very smoothly and practically without noise and seems to perform its duty easily. A little reversing switch provided with nameplates plainly marked "Rolling" and "Stabilizing" allows the stabilizer to be operated to roll the boat at will. This is useful in working off from sand bars, mud banks, negotiating ice packs, etc. In fact this has already been found extremely serviceable in the shallow waters of Toledo inlet.

Other points that have been definitely settled by the operation of the stabilizer are as follows:

That under conditions of a strong wind which had been blowing all day, with Government storm warnings hoisted all along Lake Erie, a trip was made from Toledo to Cleveland, in the evening, where with the gyroscope "off" the ship rolled up to 25° each side of the vertical, and with the gyroscope "on" this roll was quenched down to an average of 3° or less, the interesting point being that the boat steered very much steadier and made her run in as good time as on any previous trip, including calm seas, and also while being stabilized her decks remained dry.

The gyro being mounted right over the main saloon it was feared that the deck would operate as a sounding board and the noise would be objectionable. This, however, was not found to be the case. While one is conscious of some noise, especially in choppy and uneven seas, there seems to be no difficulty in carrying on an ordinary conversation. There is no noise whatever in any of the staterooms aft. It is gratifying to note also that the chief engineer and others who reviewed the

operation of the plant have reported that they are satisfied that it is "thoroughly practicable and that there will be no difficulty in keeping it in proper operating condition."

Fig. 8, Plate 33, shows an elevation, partly in section, of the plant with a few rough dimensions.

Fig. 9, Plate 33, shows the gudgeons as secured to the structural steel supports.

Fig. 10, Plate 34, shows the detail of one of the gudgeons.

Fig. 11, Plate 34, shows the detail of the shaft with principal dimensions, with outline of rotor.

Through the courtesy of the owner of the yacht automatic records of the performance of the plant have been made, extending over a number of sea trials, including also some rolling records, all of which are available for use of the Department.

The gyroscopic recorder employed to make these records is shown in Fig. 18, Plate 36.

An attachment was made to the gyro plant so that a pen upon the tape might indicate the characteristic precession movements of the gyro during stabilization. Fig. 12, Plate 34, shows such a curve. This is interesting as it clearly shows the different magnitudes of the precession movements of the gyro as they automatically adjust themselves to the neutralization of widely different wave increments applying forces from the sea to either side of the ship. Some of these wave increments require a full precessional oscillation, others requiring only a very trifling precessional oscillation. Instances are also seen where successive wave increments come in from the same side of the ship, requiring a second oscillation in the same direction for their quenching.

This diagram also shows another interesting feature, namely, how the forces of the sea arriving first on one side of the ship and then on the other are transmitted through the structure of the ship to the gyro equipment in the form of static forces, causing very great disturbances and activities of the gyro equipment, while the ship through which these forces are transmitted stands practically quiescent and free from motion (other than the incipient rolls necessary to actuate the little control contacts).

Fig. 13, Plate 35, shows records taken while the stabilizer was rolling the boat, with the gyro wheel spinning only 1,100 revolutions per minute. This record indicates that the gyro running at this speed was enabled to impart to the yacht only a trifle over a degree per cycle of the oscillations of the gyro, and this only in the middle of the roll; an amplitude was quickly reached beyond which the precession motor was unable to oscillate the gyro at sufficient amplitude to increase the rolling of the ship. At this point a balance is struck, the energization of the ship from the gyro is just equaling the natural friction increment of the yacht for this amplitude. The back reaction of the movement of the ship gradually cutting down the oscillating amplitude of the gyro against the precession motor is also clearly seen in this figure.

In stabilizing a ship with the active type of gyro no effort is made to hold the ship exactly vertical. On the contrary, the ship has full freedom in point of list, due either to distribution of load or wind or both. That is, the stabilizer holds the ship from motion, allowing it to take up any natural central position it chooses and to change this position from time to time, as conditions alter. Attempt has been made to show this in Figs. 14 and 15, Plate 35. In the latter the ship was turned back and forth with reference to the wind so as to emphasize the independence of the wind list. This is shown by the wandering line drawn through the center of the oscillations. In Fig. 14 the ship is being stabilized while in the trough of the sea, while in Fig. 15 the ship is brought in and out of the trough of the sea.

Figs. 16 and 17, Plate 36, show the rolling records while going in the trough of the sea with the gyro "on" and "off" in medium wind. The maximum amplitude is marked at several points on the chart, together with the points where the gyro was thrown "on" and "off." Fig. 16 is brought in as exhibiting one very interesting feature, namely, that the rolling of the ship is always due to an accumulation of individual wave increments. These are seen to increase quite uniformly from the right to the left when the gyro is thrown "off."

The thanks of the author are due to the many courtesies received from the owner of this yacht, Mr. H. M. Hanna, Jr., and his officers and crew.

DISCUSSION.

THE PRESIDENT:—We will be very glad to hear discussion on this paper entitled, "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Mr. Elmer A. Sperry, a Member of the Society.

MR. K. ORBANOWSKI, *Member*:—I have had occasion to follow up the development of the anti-rolling tanks of Frahm in Hamburg, and I am therefore very interested to see what progress the invention of Mr. Sperry has made in this country in the few years since he first undertook this work.

With Frahm's tanks they had especially satisfactory experiences on big ships and a certain European government undertook about a month's trial in the Atlantic with a steamer of about 3,000 tons under all possible conditions and directions of sea and wind. The result which it reached at the end of a month's experiment was that the rolling in the average decreased by about 50 per cent.

We are impressed here today with the success of this invention by Mr. Sperry for smaller vessels, and there seems to be in this country great faith in it for the big ships. So I would be much interested to know what Mr. Sperry himself thinks in this respect, what dimensions and weights of stabilizer we may expect to apply for bigger displacements, and if there is a mechanical possibility of using his invention for the steadying of large ships with the same success as has been attained with the invention of Mr. Frahm.

Referring to the advantage of anti-rolling devices for the increase of speed mentioned

by Mr. Sperry, I want to put a specially interesting test before you gentlemen which we made in this respect. We had experience with two sister ships, one with bilge keels and the other with rolling tanks and without bilge keels. There was an appreciable difference in favor of the latter, as far as I can remember about .43 knot at 29 knots.

I think that is very great proof of the value of an invention like Mr. Frahm's or Mr. Sperry's in the direction of the development of speed for the faster ships which are to come in the future.

THE PRESIDENT:—Are there any further remarks? Mr. Sperry, do you want to reply to the comments that have been made?

MR. SPERRY:—Replying to Mr. Orbanowski, there is no limit to the size of ships to which the stabilizer can be applied. The weight goes down, comparatively, as the size of the ship increases, as mentioned in the paper. We find that smaller boats require more stabilization, relatively, as is apparent, because a given wave interferes with a small boat to a greater extent that the same wave interferes with a large boat. The stabilizing unit selected for the 10,000-ton naval vessel I mentioned weighs 80 tons, including entire equipment and all auxiliaries. That is .8 of 1 per cent of the displacement. That plant will absolutely hold the ship against all beginnings of roll up to nearly 4 degrees for any single wave increment arriving from either side. For larger ships the plant should never, I would say, go above 1 per cent of the displacement. The entire plant is small as compared with the ship; you can hardly find it on board.

One word, now, as to anti-rolling tanks which were referred to by Mr. Orbanowski. These are in line with practically all attempts at stabilization prior to the work on the Worden; that is, the stabilizating moments in each instance depend for their very existence upon a certain amount of motion being first acquired or developed by the ship. When these moments are finally generated they act to reduce the roll so as to cut it down by some predetermined fraction only.

With anti-rolling tanks it was found that a certain critical condition existed between the natural period of the waves of the sea, the natural period of the ship and the period of the water in the tank which, when brought into proper adjustment, would bring about a minimum of motion of the central element, namely, the ship, and the maximum activity of the water pendulum. But it was found, upon trial, that this relation was not only critical to the point of being theoretical, but very difficult to attain and still more difficult to maintain, the wave period being non-persistent and very erratic.

The Construction Bureau of the British Admiralty after critical trials reported that the stabilization depending upon this relation, which was the only stabilization from tanks worth mentioning, could only be secured about once a year when the three relations happened to come right. What happens, however, when these conditions are wrong, as they nearly always are, is that the tanks then increase the roll instead of decreasing it.

The French and Italian governments, after careful testing, abandoned tanks for virtually the same cause.

The stabilizing tanks placed in the Imperator and her sister ship have been removed.

Our own government instituted probably the most complete set of trials with tanks that has ever been made. A vessel was equipped with no less than three stabilizing tanks—more than were ever before installed—each made adjustable, and the verdict was in a rather unex-

pected direction and characteristic of the keen insight of our officers. This verdict was that the navy did not possess personnel who could be depended upon to adjust the periodicity of the stabilizing tanks so as to bring about the described critical relation between the three elements; without this critical relation being reached and maintained, the tanks were not only worthless but more likely to be a menace than a benefit.

Among other disadvantages of tanks was the fact that the construction, together with the water in the tanks, had to run up as high as 5 per cent of the total displacement of the ship to be at all effective. The specific gravity of water being only 1, the tanks have to be very large. Furthermore, they were compelled to occupy the most valuable amidship section of the ship at its fullest beam, otherwise their lever arms were inadequate and they had to be made still larger, heavier and more unwieldy.

After years of investigation this system of stabilization has been condemned and its use discontinued. At best, all of these systems, regardless of their origin or character, are passive and seek only to diminish to a certain extent the rolling of ships.

In contradistinction to this class, the new stabilizer is offensive in its method, it approaches the proposition from an entirely new standpoint, namely, the suppression of all roll, never allowing the ship to start or begin to roll, as has been previously explained by me before this body.

THE PRESIDENT:—I am sure we are all very much interested in Mr. Sperry's paper and have been much instructed by it, and the thanks of the Society are tendered to Mr. Sperry for the paper.

The next paper to be considered is No. 5, entitled, "The Determination of the Resistance of Ships. Present Day Status of the Art," by Mr. Ernest H. Rigg, Member.

In presenting the paper, Mr. Rigg said:—"We are singularly fortunate in being favored practically every year, both here and abroad, with the results of work done in the various experimental basins. The gentlemen in charge of the tanks in this country are very free in communicating the results of their work to the Society. I therefore found considerable difficulty in bringing anything new to your notice, and nothing new is claimed for this paper, but I thought it would be of interest and value to those who are engaged in powering ships to be presented with a general statement as to the present status of the art.

"My paper has, therefore, been an attempt to summarize and bring before you in concise form as much of the modern literature on this subject as I could find. I do not propose to read the paper, as the discussion on this and the other papers will be of more value than reading through the whole paper.

"Referring to Mr. Bernhard's paper of this morning and the problems of propelling that type of vessel, Professor Sadler told us of some work done by the government, which is at present not made public. I think there is something that will be of interest to all concerned in that type of vessel in Mr. Baker's book which has been recently published; it has an interesting section on the propulsion of barges and barge forms, which probably covers a good deal of the matter that is in the government publication which Professor Sadler spoke of."

Mr. Rigg then proceeded to abstract his paper briefly.

THE DETERMINATION OF THE RESISTANCE OF SHIPS. PRESENT DAY STATUS OF THE ART.

By Ernest H. Rigg, Esq., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

When it was suggested to me that a continuation and extension of the paper I had the honor of reading before the Society in 1912 on "Fuel Economy as Influenced by Ship Design" would be interesting and of value, I quite recognized the interest and value of further light on this increasingly important subject, and in reply stated that I feared such a paper would contain very little original matter, but that if the Society would like to have placed in its transactions a review of recent published investigations, together with a review of our present knowledge on the subject of powering ships, I should be glad to undertake the task. Such a review can be made of decided value, the transactions thereby becoming so much the more useful to those who design and power ships. This, then, is the object of the paper.

The subject naturally divides itself into two parts of primary importance, one concerning fine types of ships, and one concerning full types; where the line between the two should be drawn is by no means clearly defined, but, in practice, warships and passenger liners constitute the fine types and cargo steamers the full, with, of course, some exceptions to be found both ways. Motor boats, submarines and hydroplanes are now the subjects of increasing investigation; the usefulness of the two latter types in the great war insures a measure of attention hitherto given only to the larger naval vessels. Published data are already assuming considerable dimensions, but there remains, however, plenty to occupy the staffs of the various experimental tanks the world over.

This paper will deal more particularly with general naval and mercantile types. One of the first things that strikes the reader of the various authorities on this subject is the desirability of a uniform system of notation throughout the technical world. Anyone who can do something to bring this about will have earned the gratitude of all naval architects and naval engineers.

The lucidity of Taylor's "Manual on Marine Propulsion" stands out as one of the chief merits of the book, practically all fundamental points being covered.

American writers generally follow the same lines, but, when we read recent and valuable papers written abroad, we naturally find different systems of notation in use. There is, in practice, danger of serious error in using first one reference and then another, besides the labor of reduction of results from one system to the other, so that anything tending towards an international standard is well worth encouragement and advancement.

In recent years marked reductions in the power necessary to drive a given weight of ship and cargo at a given speed have been made; the experimental tanks are justly proud of the cuts they have been able to make in the power for models submitted to them for test. They are the people best placed to keep in touch with developments so far as smooth-water results are concerned and are now producing tangible results for merchant ships of all types as well as for warships, both here and abroad.

In 1912 the author read a paper before the Society which pointed out several instances of saving due to experimentation; before and since then much has been written and something has been done to keep down coal bills. At the Franklin Institute, Philadelphia, in the same year, I ventured to suggest that the saving in coal made by the naval architect might well be handed back to him in part to provide extra subdivision and stability for passenger ships—by no means a bad reply to the question of extra first cost of additional beam and bulkheads—so that the passenger need never really know any material difference in the price of his ticket due to increased first cost of ship.

The efforts connected with twin-screw drives for full-cargo ships, both steam and motor driven, have recently shown some unusually good results. Recent colliers built for the navy are cases in point, and their trials and service results are of particular value in all similar twin-screw vessel design, steam or motor.

In recent years a strong tendency to conduct systematic experiments on ship resistance is noticeable, and for this we cannot be too grateful. Isolated pullings of models as submitted are necessary, but it is only when the lessons drawn from these experiments are followed by systematic research that the profession as a whole begins to derive benefit from the work done. We have passed from the stage of individual and disconnected experiments to that of systematic research directed along lines that are already having a marked effect in reducing power or increasing speed in shipping generally.

It should also be remembered that model experiments are only half the battle; they must be followed by a progressive trial on the measured mile in order that the design of the propellers may be verified and the performance of the machinery properly noted. This trial should be conducted at the same trim and draught as the model was towed, and this should be as near the working load draught as possible and deep enough to give proper immersion to the screws. It will not always be easy for the builders to arrange for the loading of the ship, except in the case of oil tankers; but this can generally be managed at the expense of a few hours' delay to one voyage after the vessel is in service, once the owners realize the savings that are at stake.

At the time (1910) of the publication of Admiral D. W. Taylor's manual the literature of this subject was beginning to assume good proportions. It was, however, scattered, and the naval architect who did not keep in touch with a good many sources of information was at a serious disadvantage. This book brought together the best collection and arrangement of experimental data that we have. The

work of obtaining the residuary resistances for the wide range of speeds and coefficients that is given in Figs. 81–120 is in itself a gigantic task and for which the profession all over the world is indebted in no small measure to the author and to the United States Government, in whose tank it was so largely obtained.

It can safely be said that this book marks an epoch in the methods in practical use for designing and powering ships. Shipbuilders and owners are now fully alive to the value of the tank and are keen to take advantage of all it can teach them, to their no small benefit in coal bills and better service.

Since beginning this paper—in fact, very near the ending of it—Mr. G. S. Baker's new work on ship propulsion has become available in this country. Mr. Baker summarized the present status of tank work and our knowledge of this whole subject in a very able and clear manner. He uses, in the main, the "constant" system of notation, which is perhaps not as much used on this side of the Atlantic as on the other, and his book is a most valuable contribution to the literature on the subject, the main results of recent experimentation being carefully gathered together and presented in one volume, very much my own purpose in writing this paper. As in much other recently published matter, the full-cargo ship receives considerable attention in Mr. Baker's book.

The chapter on canal towage contains information not generally available in such useful form. These two books set forth our knowledge on the subject so clearly and well that the question may be asked as to the necessity of quoting at length the papers, etc., listed at the close of this paper. To study the steps leading up to their production and the work done by these and other investigators will repay the men responsible for the dimensions and lines of our ships, both naval and mercantile. It is largely in the hope that our younger members will be helped in their researches by this brief review of present day knowledge that this paper has been prepared. The author is well aware that no new discoveries are set forth herein, but trusts that, in spite of that fact, the science of ship propulsion will be benefited by this addition to our Transactions.

It will be noted that this paper only covers the literature of our own language on this subject. At first sight this appears unfortunate and there are, doubtless, many undiscovered gems of knowledge tucked away in foreign works. In the main, however, the work of foreign investigators is summarized in the books and papers listed, and as the same are there acknowledged, no injustice is done the men whose work is thus only indirectly referred to.

The Society was founded in 1893 and the 1915 volume will be No. 23. In searching for papers it frequently happens that much time is lost through lack of a comprehensive index, therefore I would strongly urge that the Transactions be indexed, such index to be sold to members at cost price. It would be necessary to keep the index up to date, but if the work were kept up each year to prevent undue accumulation, supplementary indices could be issued every three or four years and the whole combined every ten years or so, or as the stock of the main index was exhausted.

It has been with considerable regret that I have avoided extending this paper to cover, in a similar manner, the literature of the screw propeller. It would have been impossible to adequately cover both of these branches of the subject in the time at my disposal, and I would suggest that a corresponding paper on the propeller side of the question be prepared for next year, if the council consider it worth while.

A few paragraphs follow in which matters of current interest in ship propulsion are touched on, together with a list of references which contain practically all that has been published of late years on this subject.

EFFECT OF INCREASED BEAM.

It has long been known, and acted upon, that large beam, generally speaking, involved high resistance; we realize nowadays that too high a price can be paid for small beam and resistance. Increase of beam, accompanied by increase of stability and decrease of fullness, by no means necessarily spells increase of power; for the same or less power a healthier type of vessel can generally be obtained, at, however, a somewhat increased first cost of hull material in most cases, due to increased wetted surface and wider decks.

We have arrived at a point where increased safety is demanded in passenger carrying vessels; it is no use putting in bulkheads to enable a ship to keep afloat after damage if the other danger—loss due to lack of stability in the damaged condition—is not also provided for. Loss of buoyancy and loss of stability must both be kept in mind when settling on dimensions in a given case.

The effect of this on speed and power will by no means be proportional to the increased beam, as might appear at first sight.

A far worse enemy to good driving is full waterlines in the forebody. In two recent cases of relatively fine and fast ships that have come directly under my notice, the forward waterlines were forced out by considerations of stability to the point of a marked decrease in speed when compared with similar ships of the same principal dimensions and power. This feature, also, has its limitations, for in full and slow cargo boats the exact opposite is true below a certain speed. This condition is brought out by Professor Sadler in his 1909 T. S. N. A. paper and was verified in a recent case by direct experiment for a vessel about to be laid down. While this is true for smooth water there remains the question of loss of speed in head sea. This question has recently received considerable attention and is referred to elsewhere in this paper.

It is safe to say that passenger ships generally will show a tendency to increased beam in the future, extra life-saving equipment, the natural desire of passengers for deck cabins and extra stability for damaged condition all tending the same way. This will not necessarily entail more power, because we know more about good forms and because ships are tending to be somewhat finer to give better sea performances. The cruiser stern is another way out of this difficulty.

The British Board of Trade's recent instructions to steamers in the danger zone throw an interesting light on this point, applicable almost as much to peace as to war damage:

"In order to prevent the vessel taking a sudden list if holed by a torpedo, the stability should be increased to the utmost extent practicable by filling ballast tanks or otherwise."

Another paragraph follows, relating to longitudinally bulkheaded ships of small initial stability; both these paragraphs point towards increased beam.

The same reasoning points to increased beam in our line of battleships; for a 31,500-ton ship a beam of 110 feet is already responsibly suggested abroad, and the paper by General Goulaeff before the London Institution in 1908 is well worth looking up, in the light of recent happenings. Who knows but that battleships laid down abroad since the war began are not of this largely increased beam? It is probable that less weight will be available for machinery, owing to increased protective weights; and that this, together with the new proportions, will mean a decrease in speed. The beam to draught ratio is about 3.25 in recent battleship designs, whereas in the 110-foot ship mentioned above it goes up to 4.40. In this connection, the speed curves given by General Goulaeff are of interest. The Yorktown experiments quoted by Admiral Taylor in his Manual indicate an approximate increase in power of about 11 per cent for the same speed for battleships of this displacement and with proportions varying as above.

EFFECT OF WIND AND SEA.

A good smooth-water performance is not necessarily a good sea performance; considerable attention has recently been given to this question and some interesting facts brought to light. There was the hollow versus straight lines discussion in the London Institution, 1905 (Vol. 47); Admiral Taylor referring briefly to the question in his new Manual on speed and power (p. 121). Baker in his new book also discusses this point.

Early this year Sir A. Denny referred to the matter before the Institute of Marine Engineers, citing instances of improvement in sea performances due to decrease in fullness compared with previously accepted practice. His point was that low first cost and low operating costs did not always go hand in hand.

Mr. A. Hamilton in 1911 before the Liverpool Engineering Society gave data based on the comparative performances of ships of varying fullness, all tending to show that the somewhat finer vessel (particularly forward) more than balanced the loss in dead weight per trip by an increased number of trips per year.

It is difficult to deduce any rule, but the general lines to follow are obvious—the speed curves of a design should be run well up beyond the designed speed and attention given to the characteristics of the curves at the speeds beyond the smooth-

water maximum as well as at that maximum. It may often be that an apparent sacrifice at normal speed is no sacrifice at all, but really a decided gain in coal burned per annum in a seagoing ship, particularly a transoceanic or great coastwise trader.

A paper by E. S. White before the Northeast Coast Institution (1912) is well worthy of study in this connection.

EFFECT OF SHOAL WATER.

This subject has come to the front recently in practice as well as in theory. Torpedo-boat destroyers have furnished the most interesting cases, and the subject is worth very serious consideration by those responsible for the performance of vessels running in shoal bays, rivers and lakes. The literature on the subject gradually accumulates and we are now in possession of a very considerable amount.

Admiral Taylor refers extensively to the subject in his Manual, the historical data therein give credit to the earlier investigators, and numerous references will be found in the bibliography of this paper.

It is not too much to say that knowledge of the effects, both bad and good, of shoal water is absolutely necessary to the proper running of destroyer trials, and no less so for the designing of shoal-water vessels. It will pay those charged with running big vessel trials to be very careful where they run them.

On a recent trial of a 400-foot vessel drawing 19 feet and of 15 knots speed the performance at sea in smooth water was materially better than on the measured course, due to deeper water as well as to the absence of the necessity for frequently turning to run over the course, the reduction in horse-power being about 4 per cent.

In a destroyer trial at 24 knots it was found that in 15 fathoms the power required to maintain standard revolutions was materially higher than on standardization and that on going off into deep water this at once changed.

Besides the guidance to be obtained from Taylor's Manual, his T. S. N. A. paper of 1913 on relative resistances of models with constant block and other coefficients varied contains valuable data. Baker's new book has a chapter devoted to shoal and restricted waterways that is extremely useful. Canals are an important part of shoal-water navigation, and the value of special consideration was emphasized before the Royal Society of Edinburgh as far back as 1840. Much work has been done before and since, especially in connection with the navigation of French, British, German and Dutch canals.

The navigation of the Nile and similar rivers has received special consideration for centuries.

Professor Sadler has carried out valuable experiments at the University of Michigan, his 1911 T. S. N. A. paper giving information on merchant ship forms being worthy of careful study.

Hudson River boats have received, to their no small benefit, special considera-

tion from the point of view of bank erosion as well as power saving, if it is possible to separate the two as far as rivers of moderate breadth are concerned.

CRUISER STERNS.

Of late years an increasing number of merchant vessels have been built with the form of stern considered peculiar to battleships and cruisers.

There is much to be said in their favor and the effect on speed may well be noted here; for a given overall length this stern gives the maximum mean immersed length and a resulting decrease in power and consequently machinery weight, necessary for a given speed, varying with the size of the ship, being greater in the smaller ship. The adoption of this stern is attended with increase in stability, in deck room and in protection to screws in harbor. A full discussion is to be found in the *Times Engineering Supplement* (London) of April 24, 1914.

The chief objection is increased first cost, appearance is another in some eyes, but small increased first cost will have a hard struggle against a possible 8 per cent saving in coal bills. The arguments are very much in favor of the cruiser stern for all twin or more screw designs, with a good chance in the single-screw design providing the draught is large.

Shipbuilding and Shipping Record (London) of January 22, 1914, also has an interesting article on cruiser sterns.

Modified cruiser sterns are common in our waters for ships that do a large amount of warping into and out of docks, notably in the Chesapeake Bay and similar waters; also on the coast in a few cases, some Old Dominion liners being built that way. Doubtless many other instances could be found.

EFFECT OF TEMPERATURE ON RESISTANCE.

It has been known for some time in the experimental tanks that temperature plays a part in ship resistance.

Messrs. Denny Brothers of Dumbarton are reported to have been unable to account for differences in summer and winter trials of sister ships in any other way, and the matter is also under investigation at the Teddington tank in England.

Differences in resistance as high as 4 per cent per 10 degrees difference in temperature are reported, the lesser resistance corresponding to the higher temperature.

APPENDAGE RESISTANCE.

Lately this has received renewed attention; since Taylor's experiments in the Washington tank, showing the run of the stream lines on ship models, designers have studied more carefully the placing of bilge and docking keels.

Sadler's experiments on enclosed shaft bossings have also given valuable aid in properly placing these appendages. The author recalls a large vessel which had her bossing altered to better form with the result that the speed at constant dis-

placement went up from 18 to 18½ knots. This increase in a vessel displacing over 11,000 tons was due solely to a change in the lines of the bossing.

In battleships appendage resistances as high as 25 per cent of the total have been recorded. The importance of reducing this where practicable is at once evident.

For more detailed information the reader is referred to Taylor's Manual and to Dyson's work on screw propellers.

No important vessel should be laid down without stream line diagrams at critical speeds.

The fitting of anti-rolling tanks has a small and indirect effect on resistance. The result of omitting bilge keels is a saving of about 3 per cent, which is cut in half by the extra displacement due to weight of the tanks and contained water; this saving should help to pay for the tanks and controlling gear. Anti-rolling tanks, however, undoubtedly require skilled handling and constant watching whilst at sea.

References to bilge keel and other appendage resistances will be found in the bibliography.

Baker has an interesting chapter on appendages in his book just published.

The importance of an allowance for air resistance should not be overlooked.

SUMMARY.

To sum up briefly the above notes, suggestions and recommendations, the following may be said:—

1. The system of notation used by Taylor and Sadler in presenting their results is ample, clear and direct; it is, therefore, preferable for general use.

2. The model of practically every naval or passenger design should be tested in the tank and enough models of cargo vessels similarly tested to cover a useful range of vessels, so that each yard can know whether their "lines" are good and make improvements from time to time as experience points out. This is the only real way "lines" can be compared and improved, for trial conditions vary all the time and service conditions and results are seldom accessible to builders except in a very general way. In this connection the relative smooth and rough water performances should be kept in mind.

3. For large cargo ships and practically all motor ships, a twin-screw drive is the most efficient; the two, three or four-screw drive is so well established in passenger and war ships as to need no further comment.

4. Further light is desirable on vibration problems, especially for vessels with machinery aft.

5. Speed and stability are intimately associated and generally pull at cross purposes; the temptation to small beam, high speed and comfort at sea for passengers may be yielded at the price of safety in accident.

6. We are at present witnessing the passing of the very full cargo ship at sea in favor of a somewhat finer type. This is a good step.

7. Cruiser sterns for twin or triple screw ships are decidedly to be preferred to the old type of counter.

8. Appendage resistance is generally very small in single-screw merchant ships, but cannot be watched too carefully in other and faster types. Enclosed shaft bossings are generally preferable to open brackets.

9. We are not yet ready to advocate the general adoption of anti-rolling tanks.

10. Progressive trials of important ships should always be made and enough cargo ships thus tried in load condition to check up model tank and propeller performances. This could well be emphasized towards oil tankers, on account of the ease with which they can be loaded; other types of ships of similar lines would thus also benefit.

11. Flared bows above water are now well established and undoubtedly improve performances at sea.

12. Large apertures, propellers well back from the post, and ability to unship propeller without withdrawing the tail shaft, are to be strongly recommended.

13. Competitive bidding tends to a cheaper first cost at the expense of subsequent performance, which leads to full models and poor time-keepers.

14. In conclusion I should like to point to the plea for adequate trials, made by Sir A. Denny in his presidential address before the Institute of Marine Engineers only last September.

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T. S. N. A. Transactions of the Society of Naval Architects and Marine Engineers (New York).
A. S. M. D. Journal of the American Society of Marine Draughtsmen.
U. S. N. I. Proceedings of the United States Naval Institute.
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[To this recommendation Mr. Froude took exception in a supplementary report in which he set forth the law of comparison between ships and models, illustrated the law by results of actual experiments with models

3 inches, 6 inches, and 12 inches long, and recommended model experiments as of much greater value than experiments with full-sized vessels.]

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DISCUSSION.

THE PRESIDENT:—The paper by Mr. Ernest H. Rigg, Member, on "The Determination of the Resistance of Ships. Present Day Status of the Art," is now open for discussion.

PROFESSOR HERBERT C. SADLER:—I think we should thank Mr. Rigg for bringing the matter of the resistance of ships before us in such concise form. The value of the paper, to my mind, lies in the fact that he has pointed out what can be done with experimental tanks. Some three years ago I saw a letter apropos to some experiments I had made myself from a so-called practical shipbuilder, in which he made the statement that practical men looked upon the results of experiments in model tanks as more or less of a joke, so it is very refreshing to have such a man as Mr. Rigg pay the homage that he does to the results of experiment tank work. It is needless to say that that practical shipbuilder was a shipbuilder on one of the rivers in the middle west. (Laughter.)

The question of appendages, and all those things, their resistances can be determined,

at any rate to a relative degree, very easily in experimental tanks, and it is quite common to find, for instance, that the addition of bossing to the stern will add anyhere from perhaps 6 to 10 per cent to the resistance of the net hull, and even in connection with the bossing and the angle at which the bossing is placed, we have found differences amounting to as much as 3 or 4 per cent, depending on the angle.

The cruiser stern was mentioned, and I am afraid my experience bears out Mr. Rigg's—there is no doubt that that type of stern gives you a form of less resistance than the ordinary one we have been using in the marine service for so long. I have recommended it in quite a number of cases, and recently, about a year ago, without altering the lines to any great extent, we could actually reduce the resistance of a model between 5 and 6 per cent by adopting the cruiser stern.

Even with our typical lake freighters, which are usually looked upon more or less as boxes with the ends slightly shaped, we have been able to make a difference something like 5 and 6 per cent with a very small modification of form, comparatively small, and a very slight reduction in displacement.

I just mention these few facts in confirmation of what Mr. Rigg has said, and I should like to thank him for the kind remarks he has made about the work which has been done in this country.

Sir Archibald Denny (Communicated):—The system of notation used by us in our experimental tank is to plot all our resistance results as rate curves for vessels of a standard length of 100 feet, the rate being the estimated horse-power multiplied by 100 and divided by the wetted surface.

When we publish any data we publish them as estimated horse-power spots, or curves, for the actual vessel under consideration, and anyone can convert this data into his favorite system of notation. I think it might be useful to adopt a uniform system of notation throughout the technical world for the publication of results, but this would not necessarily involve a change of system for any individual experimental tank in the filing of data. It would be impossible to get all the experimental works to agree to the uniform system of notation within their own gates, as the accumulated data are very considerable and the trouble of converting them to any agreed-upon notation would not be faced. If that be so, then an attempt to introduce a uniform system of notation for publication throughout the technical world would also be difficult because the staff of each experimental works would naturally wish their particular system to be adopted so as to save themselves trouble; that is only human nature.

I concur with the author that the benefit which has been derived from model experiments has been very great, not only to those who possessed an experimental tank themselves, but also indirectly to the whole shipbuilding business, as the exceptionally efficient vessels produced by means of these tests showed what might be done and led to further improvement.

The Effect of Temperature on Resistance.—The exact amount which should be allowed for this is not yet definitely fixed, but at present we use 3½ per cent for 10°F. on the gross resistance; that is, we take 3½ per cent upon both the skin friction and wave-making. We are still working at this, but we believe that ultimately this figure will not be greatly departed from. It would be interesting if some well-known fast passenger vessel could be tried on a proper measured mile in the depth of winter, and in the height of summer, care being taken that in both cases she is freshly out of dock and painted properly with precisely the same paint. I should be glad if my American friends would show the way in this and report progress.

I am glad that Mr. Rigg in No. 14 of his summary backs up my efforts to have adequate (progressive) trials made the rule; it is sad to think of so many opportunities of acquiring data being lost by the absence of such trials.

THE PRESIDENT:—Are there any further remarks? Does Mr. Rigg desire to say anything further?

MR. RIGG:—Mr. Chairman and gentlemen, I should like to thank Professor Sadler for his remarks, and in closing I would like to ask you to be kind enough, if you recall any references to the subject, that you will let me have them, that they may be incorporated in the final printing of the Transactions.

Mr. Gatewood has been kind enough to send some references to the classical Froude experiments, which have been added to the bibliography. These British Association papers give the pioneer work of the elder Froude, from which our modern experimental tank work all dates.

I wish to thank Sir Archibald Denny for his written discussion; he very clearly states the situation as regards uniformity of experimental tank methods. The proposed adoption of a standard method for publishing information and results is a valuable suggestion. The difficulties there to be encountered are considerably less than in the more ambitious and possibly less desirable scheme of uniformity throughout.

Regarding the temperature effect, Sir Archibald's suggestion that the same vessel be tried under identical conditions, first in the extreme of winter and then in the middle of summer, on an American course, is a very good one, because we have very materially greater extremes of heat and cold than occur in Great Britain. I should like to refer here to Mr. G. S. Baker's 1915 Northeast Coast paper on the effect of temperature on resistance both with and without modifications necessary due to the particular speed at which a vessel travels.

THE PRESIDENT:—The next paper will be No. 7, entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by Mr. W. L. R. Emmet, Member of Council.

MR. EMMET:—Mr. President and gentlemen, this paper does not contain very much text, and it is not necessary to read it. I have sought in this paper to make some comparisons between the cost of electric propulsion, exemplified by the battleship California, for which we are designing the machinery, and other methods of propulsion. Of course this comparison cannot be an absolutely just one, because I have no very good data concerning the other methods with which I am comparing—I have taken the records of tests of battleships which are some years old, turbine-driven ships and engine-driven ships, and have made certain comparisons with what the California would do if our guarantees were met.

I have also presented in this paper three plates (Plates 37–39), which show a comparison between a geared turbine-driven ship, as shown in the paper published some time ago by Sir Charles Parsons, a direct-connected Parsons turbine equipment as applied to the battleship Utah, and the layout for the California, which we submitted to the government in connection with our proposals. I made certain comparisons concerning the interchangeability, compactness and number of turbines in the three different arrangements, and these are just comparisons for these particular cases; but there are many forms of design, of course, which might be compared.

I have worked very hard to bring about this trial of electrical propulsion, and finally I have succeeded in doing so. It has taken about eight years to do it. Whether there will be any more electrically propelled vessels, I do not know. I believe the California is still regarded as an experiment, but when she is fully equipped and running the installation of electrical propulsion may popularize itself and electrical propulsion have the use which I think it is entitled to.

When I began the proposed electric propulsion there was no geared propulsion—that is, I had never heard of it, although I dare say there may have been some beginnings made—and when good engineers began to propose geared equipment I bethought myself very carefully as to whether the electric method was justified in the light of possibilities demonstrated or imagined in connection with gears. I had been fortunate enough to limit my recommendations to very definite purposes in my advocacy of electric drive; that is, I said in my first statements on the subject that it was something suited to very large vessels where large powers would be involved, and particularly suited to vessels in which economy at variable speed was desirable, such as warships. Wonderful work has been done in connection with gear drives, and the speed-reduction problems, which are the primary object of electric propulsion, have to a great extent been solved in that direction. The exact limit of geared driving is something which I do not know about, but I know that many experiences indicate that the limit is high.

This drawing of Sir Charles Parsons' design which I show here (Plate 39) is a couple of years old. It shows a very complicated arrangement, but it does not show any of the piping. This arrangement is designed for separate cruising turbines with a view to getting high economy at cruising speeds; it involves a certain degree of complication, and the different turbines are more or less tied together and dependent upon each other. One of the greatest advantages of electric drive is that you have a lot of units which are independent, two or more generating units and several motors; you are not dependent upon any mechanical connection which may be broken or impaired, you do not have to carry steam across from one turbine to another, you have a relatively simple unit, and electricity is used as a means of transmission. Another great advantage is that you can run at low speed with one unit instead of using two and make your electrical connections so that the speed is right and the electrical efficiency is always high.

In the large number of ships now being proposed in the Navy, I believe that a great field opens for electric propulsion, and that, if electric machinery is designed to drive some of these large ships, better results can be obtained than in any other way. Although the developments in connection with geared turbines are very important, they have not changed my opinion one iota as to the expediency of electric drive in the types of ship for which I originally recommended it.

SOME COMPARISONS RELATING TO ELECTRIC PROPULSION OF A BATTLESHIP.

By W. L. R. Emmet, Esq., Member of Council.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

The Navy Department of the United States has awarded to the General Electric Company of Schenectady, N. Y., a contract for electric propelling machinery for the new battleship California, which is being built at the New York Navy Yard. This ship is of the largest and most powerful class which has been adopted by the United States. Her displacement is 32,000 tons and her maximum speed is to be about 22 knots, requiring about 37,000 shaft horse-power. The contract with the General Electric Company covers two turbine-driven generating units, four propelling motors (one for each shaft), switching apparatus, cables, instruments, etc., two turbine-driven exciting units, and a complete equipment of condensing auxiliaries and ventilating blowers, all driven by motors from the exciting units. In fact it covers practically the entire engine-room equipment except the main condensers.

Each of the auxiliary units is of 300 kilowatts capacity with a 240-volt direct-current generator geared to a high-speed, non-condensing turbine. These turbines will exhaust into the heaters, into the main turbines, or both.

The motors which drive the auxiliaries will be designed for a considerable range of speed variation so that the auxiliaries will be adaptable to economical conditions at different speeds of the ship.

The award of this contract was the result of a very long campaign of education which has been conducted by the writer in which the equipment of the collier Jupiter has been an incident. The writer has from the first maintained that the proper field for electric propulsion was in ships of high power and in ships where economy at widely varying speeds was important.

The Jupiter has now been in commission for two years and has proved an unqualified success. The steam consumption of the main drive with 190 pounds pressure, dry steam, and 28.5 inches vacuum is 11 pounds per horse-power hour delivered to the propeller shafts, which is at least 30 per cent better than is done by reciprocating engines in ships of the class. There is also evidence of further saving in the Jupiter, incident to the fact that her large low-speed propellers are turned with a perfectly uniform angular motion and with entire freedom from racing, conditions heretofore unknown with such propellers.

The details of the Jupiter's installation have been described in previous papers presented to this Society. All predictions made by the writer in connection with the Jupiter have been exactly fulfilled. The following quotation from a paper by Lieut. S. M. Robinson, Chief Engineer of the Jupiter, shows the opinions of the men who have had experience with this equipment:—

"After all, the greatest test of the satisfactory working of any machinery is whether or not the men who are actually handling it and caring for it are pleased with it. If this test applies to the Jupiter's machinery, it certainly is an unqualified success. In particular is this true if the matter is referred to the coal passers in the fire-room who have to handle much less coal than do the men on sister ships. The ship can make her contract speed of 14 knots without using forced draft at all."

The generators for the California are bipolar alternators, and the motors are arranged to be connected either for 24 poles or 36 poles. For economic cruising at 15 knots or less, one generator will be used with motors on 36-pole connection. For higher speeds the 24-pole connection will be used. The ship will be capable of operating at a speed of about 18.5 knots with one generator.

Speed variation with either motor connection will be effected by change of turbine speeds through the agency of variable speed governors designed to hold automatically any desired speed within usual ranges. This arrangement, which is also used in the Jupiter, entirely prevents racing and makes it convenient to hold a fixed speed irrespective of variations in sea, weather or steam conditions. It is thought that this feature will be valuable in fleet formations.

The steam consumption guaranteed on the California covers the total steam required for the main turbines and engine-room auxiliaries as described above. The conditions are 250 pounds gage pressure, dry steam, with such vacuum as can be produced under trial conditions. The guaranteed water rates per horse-power delivered to the propeller shafts are as follows:—

	Lbs.
At 10 knots	14.6
At 15 knots	11.4
At 19 knots	11.1
Maximum speed	11.9

Very heavy penalties are imposed in case these guaranteed consumptions are exceeded in trials, $25,000 per pound for the two lower speeds and $20,000 per pound for the two upper speeds.

At full speed the California propellers will make 175 revolutions per minute, this being about the lowest speed of propellers which is practicable within the space. The propeller speeds proposed for the sister ships with Parsons turbine drive is 240 revolutions per minute, and comparisons by Dyson's method indicate that this speed difference will give the California an advantage of about 9 per cent in propeller efficiency.

The following table gives a comparison of steam consumption per effective horse-power between the California as guaranteed, the Florida and Utah which are driven by Parsons turbines, and the Delaware which is driven by reciprocating engines. These figures are taken from the published records of trials.

POUNDS OF STEAM TO MAIN ENGINES PER HOUR PER E. H. P.

	12 knots	*15 knots*	*19 knots*	*21 knots*	*Prop. speed 21 knots*
Florida	31.8	....	24.0	23.0	328
Utah	28.7	....	20.3	21.0	323
Delaware	22.0	....	18.7	21.0	122
California	17.3	15.2	15.0	16.4	175

Such a table as this affords the truest basis of comparison of prime movers in ships.

The estimated weight of the propelling machinery without condensing auxiliaries is 530 tons, and that of the turbines originally proposed was 653 tons.

The contract price for the California propelling machinery with auxiliaries given above is $431,000. The estimates made at the New York Navy Yard indicate that this equipment will cost $200,000 less than the Parsons turbine equipment previously considered.

The accompanying cuts show engine-room arrangements with three types of machinery. Plate 37 is the California. This is the arrangement suggested by the General Electric Company's proposal, but a somewhat different arrangement will actually be used. Plate 38 is the Utah, and Plate 39 a geared turbine equipment for a large warship shown in a paper by Sir Charles Parsons. Attention is called to the simplicity of piping, steam and vacuum connections with the electric drive as compared with the other methods. The California has two turbines, the Utah has ten, and the proposed Parsons geared equipment has thirty-two.

All of the steam passages between turbines in these arrangements involve loss of useful pressure, and many of them involve risk of vacuum loss through air leakage, for it must be remembered that ships are often subject to vibration and that there may be appreciable relative motion of these different parts through expansion strains or working of the ship, or through their own inertia when the ship is vibrating or laboring in a seaway.

The advantages and simplifications incident to electric drive are greatest in such large warships as are here shown, but they apply in only slightly lesser degrees to all large high-power vessels.

DISCUSSION.

THE PRESIDENT:—This paper by Mr. Emmet is now open for discussion.

MR. JOHN PLATT, *Member:*—The remarks that have just been made by Mr. Emmet in regard to his paper that refer to some of the illustrations that go with his paper, I presume cover the case and may take away from something I am going to say; but as he has written his paper and published these illustrations in his paper, and as they form part of the paper, I take it that it will be in order if I give a few facts with regard to the designs of turbines with mechanical reduction gear, particularly those to which he refers in the paper.

In the fourth paragraph, p. 71, Mr. Emmet tells us that the award of this contract for the California was the result of a very long campaign of education and further refers to the collier Jupiter, the only marine installation of electric reduction gear under this system that at present exists. The author seems to think he has been a very long time in getting recognition. It seems to me he really should be very much gratified to have obtained so quickly the opportunity of trying out this form of drive in a fifteen-million-dollar battleship. In spite of the fact that there are some twelve million horse-power of Parsons marine turbines in different parts of the world, and three million horse-power with mechanical reduction gear, the Navy Department did not consider the use of this most successful mechanical reduction gear in the proposals submitted by the navy yards for the propelling machinery of the two newest battleships.

In the last paragraph on page 72, the revolutions of the California propellers are given as 175 per minute. This number of revolutions the author contrasts with the 240 revolutions of the direct-driven Parsons turbine ship Idaho, and concludes that there is an advantage to the electric reduction gear of about 9 per cent in propeller efficiency. This he derives from Dyson's method. It should, however, be unnecessary to point out that to make the comparison useful to engineers and shipbuilders the 175 revolutions of the California should be compared with the 200 revolutions used in the Parsons layout with mechanical-reduction gear.

The first paragraph on page 73 compares the expected steam consumption on the California with that of the Florida and Utah fitted with Parsons turbines. The author then states that the figures given in the table "afford the truest basis of comparison of prime movers in ships." This would be true if the ships were of equal size, and if the Florida and Utah were fitted with reduction gear. Surely the author does not expect the members of this Society to agree with him that a comparison such as he proposes is a proper one. The Florida and Utah are older ships, are of 50 per cent less displacement, with the straight drive, and with no reduction gear.

In the fifth paragraph we are referred to the illustrations that accompany this paper. We are told that Plate 37 is "the California," but that the arrangement shown is not the one which will be used. If comparisons are to be made, may we not properly ask that the machinery that is actually to be used in this ship be illustrated in the Transactions of the Society in place of the arrangement shown in the advance copy?

In Plate 38 he illustrates the turbine and piping arrangement of the Utah, and in Plate 39 what he calls "a geared turbine equipment for a large warship shown in a paper by Sir

Charles Parsons." As the author then calls attention to the simplicity of piping, steam and vacuum connections with the electric drive as compared with other methods, and states that the California had two turbines, the Utah ten and the proposed Parsons geared equipment thirty-two, he evidently wishes it to be understood that the basis of comparison proposed is one worthy of our consideration.

Plate 39, which we are asked to compare with the layout of the California, is taken from a paper entitled "Mechanical Gearing for the Propulsion of Ships," read on March 13, 1913, before the Institution of Naval Architects; the sketch from part of Plate VII accompanying this paper, the title being "Geared Turbine Machinery for Battleships with Separate Cruising Installation." The description in the paper refers to it as "a further design for a battleship of about 60,000 shaft horse-power with geared turbine machinery on four shafts, which also includes an additional set of small turbines and gearing for use when cruising."

We have this arrangement put before us for comparison with the California, when on Plate VI of the same paper is illustrated the "Typical installation of geared turbine machinery for a battleship," which is described as follows:—"Design for a battleship of about 40,000 horse-power with four shafts at 200 revolutions per minute." In the arrangement illustrated there are two turbines geared to each shaft, the turbines on the two shafts on either side of the ship being arranged in the well-known four-cylinder triple formation, each group consisting of a high-pressure, intermediate-pressure, and two low-pressure turbines, an arrangement which leads to a high efficiency both at full power and at cruising speed. With this typical arrangement illustrated in the same paper and described in the way that it is, it hardly seems fair to put before us the special arrangement shown by the author in Plate 39 of his paper as if this were the regular Parsons geared arrangement for a battleship.

Mr. John F. Wentworth, *Member:*—Last year I made some remarks on the present subject in connection with the paper read by Mr. Robinson. The questions which I asked were not answered to my satisfaction. No doubt a good deal of the fault lies in the fact that I was not favored by being present at some of the early discussions on this subject by Mr. Emmet. Perhaps he can clear this matter up at this time so that I may be able to understand the reason for this type of marine plant.

My understanding of the proposition is that the advantage lies in its greater efficiency as compared to the reciprocating type of engine. As I understand it, of the power of the turbine about 7 per cent is wasted in producing current in the generator. Then from 5 to 7 per cent of the output of the generator is wasted in the motor. This waste comes about because the turbine is not well suited for direct drive of large-sized marine propellers.

In reply to my questions of last year, when a comparison was made between oil engines and the turbo-generator plant, the oil engine was condemned on account of its present state of development. Apparently the mistake was made in supposing that I was advocating some of the present Diesel engines. There is but one Diesel theory, and all the present engines show signs of the Diesel fallacy which last year I attempted to prove, and which proof can be accepted in view of the lack of any attempts to refute my statements.

The next point to be taken up in the reply was the record of the sister ships Jupiter and Cyclops. An efficiency curve for the Jupiter was plotted from the two points given in Lieutenant Robinson's paper. This was of course a straight line. The efficiency curve of the Cyclops was drawn in from the comparison of the fuel consumptions at the same speeds with the efficiency of the Jupiter. Where the efficiency of the Jupiter at 10 knots was

given as 7.3 per cent, the efficiency of the Cyclops would appear to be about 4.8 per cent. The only thing to do was to write to the Navy Department and find out the solution of the problem. There was absolutely no question in my mind but the solution existed, it only being a matter of finding this explanation. If these figures were correct, then some very grave fault must exist in the Cyclops.

I wrote to the Navy Department and the following letter was received:—

File So. 160340-639-D

NAVY DEPARTMENT,
BUREAU OF STEAM ENGINEERING,
WASHINGTON, D. C., *July 22*, 1915.

SIR:—The Bureau has no definite knowledge of the source of Lieutenant Robinson's data, but presume they were obtained from the Cyclops. Examination has, however, been made of the logs of that vessel, and the following figures obtained for the speeds noted in your letter:—

10 knots.....71.5 tons.
11 knots.....78.5 tons.
12 knots.....86 tons.
13 knots.....94.5 tons.

The above figures are from a number of voyages. The Bureau has no information as to where Lieutenant Robinson's figures were obtained, but as he was engineer officer of the Jupiter, they are presumably from runs made by that vessel.

Very respectfully,

(Sgd.) R. S. GRIFFIN,
Engineer-in-Chief, U. S. N.,
Chief of Bureau.

The comparison between the Jupiter and the Cyclops according to Lieutenant Robinson's paper was:—

Speed	*Jupiter*	*Cyclops*
10 knots.	50.5 tons.	78 tons.
11 knots.	57 tons.	81.5 tons.
12 knots.	66.5 tons.	87 tons.
13 knots.	81.5 tons.	93 tons.

The report of the trial published by Lieutenant Robinson gives the coal consumption of the Jupiter as 54.08 tons per day at 10.01 knots speed and not as 50.5 tons. The letter from the Navy Department which is published above gives the correct figures for the Cyclops.

Another reason for doubting the supremacy of the turbo-electric type of plant is found on page 190 of last year's Transactions:—"These propellers (the Jupiter's) were designed by Capt. C. W. Dyson, U. S. N., and show a remarkable efficiency, giving the same speed as her sister ship on from 300 to 800 less horse-power."

In the torsion meter records for the 24-hour run at 10.01 knots, the figure for horse-power was 2,015. If the Cyclops had to develop 300 more horse-power to get the same speed, this would bring the coal consumption of the Jupiter up to 63.2 tons in place of the 50.5 tons stated if the efficiency of the Jupiter's propellers had been reduced to the same level as the Cyclops' propellers. (This point was brought up last year by Mr. E. A. Stevens, Jr.) This is a most important point if true. To accept this statement without reservation would favor the reciprocating engine. Furthermore, the speed and power curves of the Jupiter and Cyclops show that the Jupiter consumes more power for the same speed than the Cyclops. If the statement of Lieutenant Robinson is based upon experiments upon a model of the propeller, then the unreliability of the torsion meter will be further demonstrated. The question of the torsion meter will be taken up later.

The turbine of the Jupiter consumed 11.68 pounds of steam per shaft horse-power. The auxiliaries consumed about 3.12 pounds additional. Some of this is not properly chargeable to the propelling machinery. The Jupiter has 193 pounds at the boilers and 185 in the engine-room, with 168 at the turbine. This is the best condition, namely, at full speed. The California makes a guarantee of 11.1 pounds of steam for the turbines and engine-room auxiliaries with dry steam at 250 pounds gauge pressure.

In regard to this steam consumption, the following report upon reciprocating engines built by the firm of Sulzer Bros., Switzerland, is interesting. It shows that reciprocating engines have been built in the past which will compare very favorably with this proposed type of plant. The figures are as follows for these tests:—

Normal cylinder dimensions.	R. P. M.	Initial pressure.	Temp.	Vac.	I. H. P.	Steam per hour.
3000 I. H. P., 32½, 47¼, 58x59″ Stroke..	85	188	606	28	2860	8.97
		190	397	27	2890	11.28
3000 I. H. P., 34, 39, 61 x 51″ Stroke	83.5	189	913	27	2908	9.41
		196	381	26¼	3040	11.41

From the foregoing there seems to be a reasonable doubt as to the ability to make any important advance through the turbo-electric combination. An advance in efficiency seems to be contemplated in the California over the Jupiter. A part of this gain must come from improvements in the turbine. Some of this efficiency is due to improvements in the boilers, which improvements would aid a reciprocating engine as well as a turbine. The Jupiter had 190 pounds of steam at the boiler and 168 at the turbine. The California is to have 250 pounds. This is probably at the boiler. Allowing for a vacuum of 1 pound in both cases and for saturated steam in both cases we can get the maximum possible efficiency from the formula $\frac{T-T'}{T}$. T is the absolute temperature or the glass reading plus 460. From our steam tables we can get the temperatures:—

T' (at 1 lb. pressure absolute) is 102° F. plus 460 equals 562.
T (at 190 plus 15 absolute) is 384° F. plus 460 equals 844.
T (at 250 plus 15 absolute) is 406° F. plus 460 equals 866.

Maximum theoretical efficiency of Jupiter is $\frac{844 - 562}{844}$, or 33.4 per cent. Maximum theoretical efficiency of the California is $\frac{866 - 562}{866}$, or 35.1 per cent.

Under this condition, the gain in efficiency due to use of higher pressure steam is $\frac{1.7}{33.4}$, or 5 per cent. In view of past records quoted for reciprocating engines, it is hard to see how any considerable advantage can be hoped for with this type of plant.

Fig. 3, Plate 40, contains the coal consumption curves for the Jupiter and Cyclops as Mr. Robinson gave them in answer to me last year.

Fig. 4, Plate 40, contains the same curves corrected as far as I have been able to get reliable data. It will be noticed that the curve from 10 to 11 knots for the Jupiter is practically level. This makes me think that Lieutenant Robinson's figures for the coal consumption from 11 to 13 knots inclusive are in error. The four figures for the Cyclops and the figures at 10 and 15 knots for the Jupiter are as reliable as it is possible to get data.

In Fig. 2, Plate 40, are shown speed and power curves for the two ships. I wrote for official figures from the Department, but have been unable to get the data. These curves have been constructed by comparing with the cube of the speeds. The accuracy of this method is shown by the fact that the shaft horse-power of the Jupiter figures out 2,125 and is given by trial as 2,015. This proves that the shape of these curves cannot be far out, and the upper points are fixed by trial trips. The trial of the Cyclops gave 6,705 indicated horse-power at 14.67 knots. I understand that it is the practice of the Navy Department to consider a new engine to have an efficiency of 90 per cent. This will give the shaft horse-power of the Cyclops as 6,034 in place of the 6,705 indicated horse-power. The Cyclops and Jupiter are sister ships and are designed to drive at 14 knots with 5,500 shaft horse-power. The shaft horse-power of the Jupiter by torsion meter was 5,830 and for the Cyclops was 5,370, both from the curves.

Without going into this matter in great detail I question the torsion meter results. Lieutenant Robinson told us that the Jupiter had the better propellers. I feel that we are at least entitled to assume that the propellers were equal. If this be so, then the speed and power curve of the Cyclops is more accurate for the Jupiter than the results given by the torsion meter installed on the Jupiter. I have taken this curve and, by comparing with the coal consumption curves, have constructed the efficiency curves shown in Fig. 1, Plate 40. The efficiency here represented is service efficiency. If Lieutenant Robinson made an error in the coal consumption for 11, 12 and 13 knots speed, the Jupiter's curve could be flattened out to assume a shape more like the Cyclops. However, this shows that the Jupiter is the better ship at cruising speeds. We can question steam consumption, but we cannot question coal consumption. This is one of the points which I always try to get to. In this way all classes of prime movers can be compared. The comparison is final. Then by doing this a better idea of possible gains or losses can be arrived at.

It may be said that it is of little importance whether the torsion meter is correct or not. There is another point to be considered. In this case the plant is being sold by torsion meter. For this reason it becomes of utmost importance that the torsion meter be accurate. I feel that I have more reason to state that the curve for the Cyclops is correct for the Jupiter than an opponent can have for insisting upon the accuracy of the torsion meter.

Correcting for this error in the torsion meter we find that the steam consumption at 10 knots becomes 12.65 pounds in place of 12.316, and for 15 knots 11.68 pounds becomes 12.95 or perilously near the guarantee of 13 pounds.

In regard to the steam consumption of a prime mover the only fair way to handle this matter is to measure all steam used in connection with propulsion. The Jupiter was run for three days on trial. For two days her auxiliaries consumed 22,212 pounds of steam per hour. For one day, the third day, they consumed 15,246 pounds per hour. This difference is 6,966 pounds of steam per hour. The horse-power was reduced by 4,480 in terms of shaft horse-power (Cyclops data). This presumably was the only difference in the three days' run. By reduction in power 1.55 pounds of steam were saved for each shaft horse-power cut out. This should be charged to the propelling plant, even if it be not used in the engine-room.

The contract for the California calls for a certain steam consumption for turbine and all engine-room auxiliaries in terms of the shaft horse-power. From the data given out by Mr. Emmet and Mr. Robinson it is very hard to see how the guarantee can be attained.

This argument is of more importance in showing up a very grave fault in engineering practice than it is in connection with the performance of the turbo-generator plant. Last year I spoke on this subject to draw attention to the great advantage of the oil engine over the steam engine. The fact that a reputable engineer should have disputed my figures of 11 per cent for the efficiency of the Jupiter without any more proof or reason than because "I know it is more than 11 per cent, or we would not be using it" shows a great need for an analysis of our figures concerning the operation of power plants. Personally I never accept the results of a test by itself. Errors are more apt to creep into test than into theoretical considerations of plants.

Coming back to the turbo-generator plant, it is not denied that there is a loss of around 8 per cent in the motor-generator set. The turbo-generator plant is a motor-generator set with a turbine thrown in. There is every reason to expect that there is a loss of 8 per cent in addition to the losses in the turbine. The figures presented by Mr. Robinson, and indirectly used by Mr. Emmet to uphold his contention for the superiority of this type of plant, show the great danger in using figures given in actual operation to prove a contention. Such figures should always be checked by a comparison with other data, and when the results are favorable to an unreasonable degree the figures should be generally rejected till explained by some reason. If wonderful results be obtained for which sound reason cannot be given, it is well to consider the data very carefully before accepting it. It was the discrepancy between the Cyclops' figures and the figures of the Jupiter that made me write to the Navy Department for an explanation.

It is my opinion that this series of papers and discussions has clearly demonstrated that the torsion meter should not be depended upon as a measure of power. If this be impossible, the torsion meter should be calibrated with the utmost of care.

It is an unfortunate condition where the boilers are furnished by one contractor and the propelling machinery by another. In a case of this sort there is a great chance for trouble in regard to the responsibility for the final economy of the vessel. In the case of the Jupiter it is apparent that 1.55 pounds of steam per shaft horse-power were used to get the extra results needed by the increase in speed, but this steam is not charged to the propelling plant. This most clearly shows the need for basing all results upon fuel consumption, as I stated last year. If this be done, the engineering fraternity will be brought face to face with the low efficiency of the steam plant, and experimentation will result to rectify this. This condition will be objected to by the boiler manufacturers, but as engineers it should be our aim to investigate conditions regardless of whom is hit by the investigation.

Finally, it is no more than just to say that I have been converted to a belief in the

turbo-generator plant for naval work if steam is to be used as a prime mover. My change comes simply and solely from a consideration of the curves of efficiency shown in Fig. 1 of my plate (Plate 40). It is in spite of the erroneous claims which have been made for this type of plant. This figure shows, not that the turbo-generator plant is superior at all conditions shown, but it does show a gain in efficiency at cruising speeds which is the most used condition in the Navy. To be consistent with my previous statement that such facts should not be taken without a reason, some explanation for this condition should be found. I have satisfied myself that a perfectly good reason exists why the turbo-generator plant should be only equal or slightly inferior to the reciprocating plant at full load and superior to it at cruising speeds.

My entrance into this discussion last year was to combat some of the extravagant claims made for this type of prime mover. Had these claims been correct there would exist but little incentive for me with others to work in developing the oil engine for this service. However, this argument proves conclusively that the efficiency of this plant is at its best not over 11 per cent. I have shown how theory is better than practice when practice is carelessly used. Last year no objections could be raised to my statements that it was possible to build an oil engine of from 25 to 36 per cent efficiency.

Under these conditions I feel that while the supremacy of the turbo-generator plant, for naval work alone, is fairly well demonstrated as far as the conservation of fuel is concerned, the oil engine by reason of its much greater efficiency and small amount of space occupied is unquestionably the superior of all the known forms of prime mover for maritime uses.

Mr. John Reid, *Member*:—I would like to say a word on this subject from the standpoint of the naval architect. You get certain views about electrical propulsion from marine engineers, for and against, but the naval architect must look at this thing from an entirely separate standpoint. I will show you by a diagram what I mean.

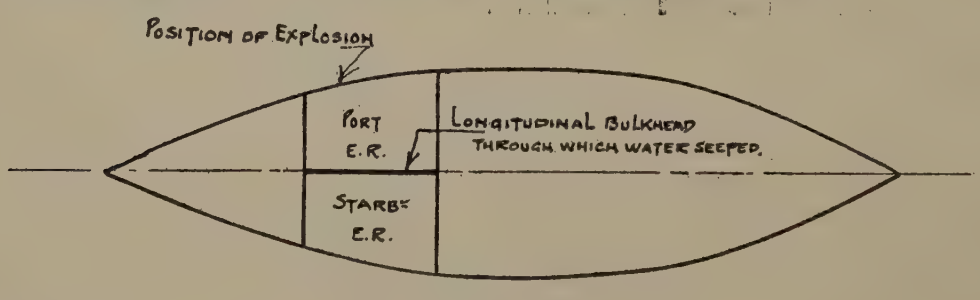


Diagram showing Position of Engine Room and Point of Explosion.

I think you are aware that there is a good deal of surprise in the minds of naval architects as to just why certain vessels which have recently been lost through mining and submarine activities actually went down, referring to both warships and merchant vessels. One large warship which was recently lost was hit in the port engine-room. I will make a small diagram of what I mean. Here is the engine-room of that ship, we will say (indicating on the diagram on blackboard), and there are two engine-rooms for the four sets of turbine engines. The ship was hit here (indicating) by a very small bomb or mine, and this bulkhead (indicating) was not damaged at all, but the water got through from one engine-room to the other, and as she gradually listed over she had to be abandoned and went down. Those of us who have been familiar with merchant practice are not very much surprised

when a warship, which is hit under the water, goes down, because we know that naval constructors attach so much importance to guns and armor that when you look at a warship critically you are astonished at its lightness under water. It may be staunch enough ordinarily, but when hit by a torpedo or mine the result is almost certain to be fatal. In the cases of the Lusitania and the Empress of Ireland, in which the same thing happened, the ships with large wing spaces lost stability and went down.

Where electric propulsion comes into the thing is this—the marine engineer will want to concentrate his marine engines, whether electric or any other, in the smallest and fewest spaces possible. He wants to bring them together for various reasons which I do not need to discuss, but if you are going to improve the safety of large vessels, war or merchant, against mines, torpedoes, collisions at sea, etc., you find it the very simplest plan with electric propulsion to stretch out your power along the ship's length as far as possible. Suppose that is the ship, looking down into the engine-room (referring to diagram on blackboard) and this is the normal engine space (indicating) and boiler space here and bunkers on either side. Now, if that ship is hit anywhere near the engine-room, or if the ship is struck near the boilers, the whole power of the ship is lost and you are done for, and you cannot do anything to save the vessel.

My idea is that the great advantage of the electric propulsion is that you can take your power generators and spread them out over the ship. For instance, you might have a series of generators—four, six or eight, whichever you like—in a central longitudinal engine-room, with one or two in each space, boilers on either side of them, and in the space outside you can have the longitudinal bulkheads, water ballast tanks, fuel, bunkers, etc. That enables you to drive your machinery into small compartments, to get your machinery divided so that it cannot be put out of business by one torpedo or mine, and then you can have your four propelling motors, or whatever it is, located in another closed space, and the power communicated to them by the usual methods.

That is a point of view which the marine engineer does not take hold of—he does not want it—he does not like it; the machinery is too much scattered about. You have to do these things if you want the advantages, from the designer's standpoint, which come from them.

I will give you a case where I can also see the advantage of electrical propulsion. What I mean to say is, a case not merely of coal consumption or mechanical efficiency, or this, that, or the other thing; it is a case of being required, you need electrical propulsion, you do not want to put it into ships where you can get the same results with geared turbines, but there are cases where the electrical propulsion is essential, no matter what the other elements are. Here is a dredge, a very large one, which I am working at just now, and there is a tremendous hopper here, carrying 10,000 tons, nearly 300 feet long. For certain reasons of trim you have to put the boilers forward, and you have your pumping engines aft, and also in a central space at *B* (indicating on diagram on blackboard). You cannot design that dredge

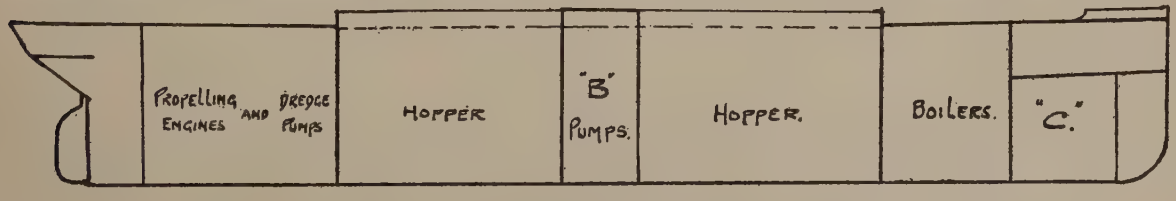


Diagram showing disposition of machinery and pumps in large dredge.

in that way unless you use electrical propulsion—it is a matter of 6,000 horse-power. Not only do you have to put these pumps in comparatively small spaces and distribute the weights evenly throughout the ship, but you have many other auxiliaries also requiring power, for instance, you might want to put pumps at *C* (indicating) for certain reasons. The moment you find it possible to use electricity in that connection you know you have a solution. Without electricity you could not adequately solve it. The dredge would not be nearly so efficient. That is entirely independent of questions of economy and efficiency. Electric propulsion is not going to make any vessel any less efficient in economy or in any other way.

To those of you who are still skeptical I can only say this—while this country has started the thing other countries are following it up very rapidly, and our Swedish friends are after it and have done some wonderful work; and instead of being skeptical I suggest that those who have peculiar problems to solve in warships and in merchant ships should get into the procession, because they will be late if they do not get in line now.

Mr. E. A. Stevens, Jr., *Member*:—I presume that some of you who have been here for the last two years will expect me to uphold the reciprocating engine, having done so before. I will say that, for certain cases, my opinion of the reciprocating engine is exactly what it was. In the last few years, however, great strides have been made in the geared turbine, and I think this system has a much larger field than it had heretofore.

Before discussing the paper by Mr. Emmet, I would like to make a few remarks on what Mr. Reid has been talking about. First of all, he speaks of a turbine battleship having been sunk in this war. I know of no turbine battleship having been sunk, but have read of one being damaged. I have also heard that this ship is today on the firing line as well equipped and in as good condition as any ship in that navy.

Mr. Reid showed a sketch here suggesting splitting up the coal bunkers, fore and aft. I think that is not only unnecessary, but is inadvisable. Some of you probably have had the experience of trying to cart coal from one bunker through another to the fire-room, passing through small watertight doors, and know the difficulties attending this; and I think will appreciate that, when trying to get speed out of a ship, the closer we have the coal bunkers to the boilers the better. The protection that coal gives in proportion to the armor on the side of a battleship is so small that it can be neglected, and this protection only exists when the bunkers are full. Besides, these ships have an inner skin as a rule, and between this inner side and the engine-room there is a longitudinal bulkhead.

Mr. Reid spoke about cases where electrical propulsion was absolutely necessary. I shall not go into that question, although I do not agree with him, because I intend to restrict my remarks to purely seagoing ships.

In regard to Mr. Emmet's paper, I will first make a few remarks about the Jupiter. I happened to be looking over the Transactions of the Society of Naval Engineers in regard to the coal consumption of the different colliers, and I found, much to my surprise, that the coal per horse-power per hour of some of the reciprocating engine ships was practically the same as that of the Jupiter. This Mr. Emmet might attribute to the efficiency of the boilers. However, the boilers on the Jupiter were very efficient—if I remember rightly the actual evaporation was something like 9.5 pounds of water per pound of coal—and when this result can be obtained with Scotch boilers, under the conditions the Jupiter was running, there is no reason to find fault.

I would like to ask Mr. Emmet, if he desired to make a fair comparison between the

geared turbine and his electric propulsion, why he did not show the last slide shown on the screen (Plate 42), instead of the most complicated one shown by Sir Charles Parsons, as the two were published in the same paper. I understand, however, that Sir Charles Parsons did not advocate seriously the arrangement of geared turbines shown in Mr. Emmet's papers. It was only a suggestion.

The question in regard to having only two turbines, or a number of turbines, is one worthy of consideration. It is not always by reducing the number of parts that we get the best results. The officers of the Navy, I think, will bear out the statement that when they come to their periodical overhauling and lifting the cases of the turbines—which is required by the regulations—that they would rather lift four or eight small casings than two large ones. It is true that the piping on the electrically driven battleship will probably be simpler than that of a battleship fitted with the geared turbines. Mr. Emmet does not, however, mention that in place of the extra piping he has electric wiring. I have heard remarks about the Jupiter's outfit being simple—you get aboard this ship and see very little. However, all the wiring is encased in conduits and is out of sight; if this were exposed to view a different impression might be had.

The question of economy is one which has been considered very seriously in the Navy lately, and rightly so. In comparing his proposed ship to others in regard to this point, Mr. Emmet makes no reference to one of the Navy's latest ships, namely, the destroyer Wadsworth. The economy shown by her geared turbines is remarkable, and although we cannot compare the Wadsworth with a battleship on the basis of water consumption, per effective horse-power, or pounds of fuel per knot, we can, however, compare the water consumption per shaft horse-power, and in this case the electric outfit would be inferior. Provided that the geared turbines were fitted with propellers as efficient as the electrical propelled ship (and I can see no reason why this could not be done), the water or fuel consumption per knot would be far superior, in favor of the geared turbine.

Mr. Ernest H. B. Anderson, *Member:*—Mr. Emmet's paper is most interesting, but he is dreadfully hard on the designers of ordinary reciprocating engines, all of whom are highly experienced men in the profession. The author informs us that an installation of electric motors for ship propulsion is best suited for large high-speed vessels, but I do not think this method of propelling vessels will ever become popular, and any large installations will really be of an experimental nature. The danger from damp and the constant presence of salt, such as exists on board ship in all the engine-rooms, will be a continual source of anxiety to the engineers.

If the U. S. S. Jupiter does give a water rate of 11 pounds per shaft horse-power per hour for the turbines only at full power and shows a good propulsive coefficient at this speed, then it is a splendid performance, but it is very unfortunate that the steam consumption for "turbines only" was not measured during the official trials of this vessel.

My experience of steam consumption measurements in terms of shaft horse-power obtained from torsion meters shows that the data are rather unreliable, and if a true relation between the quantity of steam supplied to a turbine and the propeller output in terms of speed is desired, then the calculations should be on a basis of steam consumption in pounds per knot run.

I have plotted the coal consumption data of the Jupiter recorded on the official trials with that of six other similar colliers which have twin-screw reciprocating engines, and the results show in favor of the reciprocating engine ships (see Figs. 1 and 2, Plate 41).

I do not agree with the author or Lieutenant Robinson that the greatest test of the satisfactory working of any machinery is whether or not the men who are actually handling it and caring for it are pleased with it.

Such a test is of vital importance, but the greatest test is the one which interests the shipowner; that is, how does this type of machinery compare with other methods as regards coal consumption, cost of operation, and upkeep?

Fig. 2, Plate 41, shows that the Jupiter burns a large amount of coal, and I think operating costs must be and will always continue to be very heavy, as specially trained electrical engineers are required to operate the machinery.

The data published by the author giving the contract conditions of the California are specially interesting to marine engineers, and I think the General Electric Company has remarkably easy conditions to fulfil. The only point I am not clear about is what is meant by maximum speed. If no definite speed is given in the contract, then the conditions of the high-speed test are simplified. The penalties to be imposed if the guaranteed steam consumptions are exceeded on the various trials would not cause me any uneasiness, as shaft horsepower is very much a variable quantity.

The weight figures given amuse me. Nothing can be gained in discussing this point, as both sets of figures are estimates, and probably the comparisons may not be just.

Mr. Emmet points out that 21 knots speed of 175 revolutions for the propeller wheels is about the lowest which is practicable for the space available. I hardly think these propellers will give the California an advantage of 9 per cent over the other ships at 240 revolutions, for the strut brackets which support the propellers will have to be exceedingly long, and I am strongly of the opinion that this will cause considerable vibration. Backing at full speed and full revolutions will hardly be possible, as the chances of causing damage to the ship's structure at the stern of the vessel will be great.

I have prepared a lantern slide (Plate 42) of a four-shaft all-geared turbine machinery arrangement for a U. S. battleship having similar dimensions to the California, and it was very disheartening that the Navy Department did not see their way to consider such a proposal at the time that the California estimates were in course of preparation. The New York Shipbuilding Company, Camden, N. J., submitted a bid to the Navy Department last year for a four-shaft all-geared turbine installation in a battleship, and this bid was lower in cost than alternative proposals with other direct-driven turbines.

There are four independent sets of turbines together capable of developing 32,000 shaft horse-power at 200 revolutions of the propeller wheels, giving a speed of 21 knots to the vessel, and under maximum conditions a speed of 22 knots will be possible.

The leading advantages of such an installation are as follows:—

First, good economy at full power and cruising powers.

Second, the calculated weights of the turbines and gearing amount to 380 tons, making a large saving when compared with electric or direct-driven type.

Third, independent control of each shaft, and it is practically impossible to put such a machinery installation *hors de combat.*

Fourth, nothing about an installation of this type can be regarded as experimental. Its success is a foregone conclusion. The total power of each shaft corresponds to the power developed by each shaft of the twin-screw geared turbine destroyer Wadsworth completed by the Bath Iron Works, Bath, Maine, this last summer, and this vessel is showing remarkably fine economy in commission. (Reference:—Journal of the American Society of Naval Engineers, August, 1915.)

Fifth, to obtain specially high economy at the lower speeds, largely for use when the ship is off on a long cruise, I have indicated to the dotted lines an additional pair of geared cruising turbines which will further improve the economy of the machinery at 10 to 12 knots.

Sixth, this type of turbine can be manufactured very cheaply, and there are no heavy and unwieldy parts to be moved about in the shop during its construction, and, in addition, the design is found to be very rugged.

THE PRESIDENT:—Is there any further discussion on this paper? If not, we will call on Mr. Emmet to close.

MR. EMMET:—I made some memoranda concerning the different points raised. With reference to the comparison of 175 and 200 revolutions per minute referred to by Mr. Platt, I did not know what the economy of this Parsons turbine equipment was and did not attempt to make any comparison with it. I simply put the drawing in there to show a certain arrangement which at one time was recommended by Sir Charles Parsons. The difference between that drawing and the others shown, which they say I should have put in my paper, is this—that one of them, the one which I did show, shows separate cruising turbines. The cruising turbines have been thought desirable in connection with such things, as evidenced by the fact that they have been embodied in the Pennsylvania and Nevada, somewhat different from this arrangement, but the purpose of the cruising turbine is to give better efficiency at low speed. That is one of the functions of electric drive. I do not know how these equipments of Mr. Parsons would compare in economy, but I do know that the one without cruising turbines must be relatively uneconomical at low speeds. I have selected this for comparison because we also use the equivalent of separate cruising turbines when operating at cruising speeds.

As to the comparison with the Florida and Utah, which I make as a comparison with the test results, the only information I have concerning these ships is in the reports of their trials with such propeller speeds as they use, but these propeller speeds are incident to the design of their machinery, and it is perfectly proper to compare with them as they are. If I get an advantage in the matter of propeller speeds it is an advantage of type, and the comparison is with actual ships. I am not undertaking to compare with geared ships; I am comparing with the existing battleships, with the Delaware, which is a reciprocating engine ship, and with the Florida and Utah.

The illustration which I show is my own conception of how much machinery might be put into the California. The government has seen fit to put it in there differently. That is not my fault. I think my own plan is practicable and brings the machinery more near the center line and more out of the way of torpedoes, and, if the space is available, it would seem to be desirable. Furthermore, I am not entitled to advertise the government's plans with regard to the California—in point of fact, I have been strongly criticised for publishing what I have. I have felt authorized to talk about it to this extent because these figures and all these matters were made public at the time we were bidding on the plans against the Westinghouse Electric & Manufacturing Company. They were given copies of our proposals, everybody saw it, and I understood it was public. The Department has taken some exception to my paper, I understand, but I have not heard of it directly. It is an illustration of the possibilities, I show all of the necessary parts there, and I think they could all be put into that space. The title of Plate 39 is "Proposed Arrangement for a Large Battle-

ship with Parsons Drive, Taken from Sir Charles Parsons' Paper of March 13, 1913." That is all I can do. The fact that the battleship is large is no reason why it should be more desirable to make it suitable for good economy at cruising speed than if it were smaller. We might assume that it was also desirable to put these various arrangements in the California in order to give her economy at the cruising speed. I used that simply as an illustration. I think the comparison as to the details of the number of parts is amply justified.

Another speaker has mentioned the question of the percentage of loss in electrical apparatus. He makes it sum up to 14 per cent, but in point of fact the actual electrical losses by test of the apparatus on the Jupiter are only 8 per cent. I have seen a motor generator set, where it was taking power as a motor and driving a generator, give an efficiency of 94 per cent, that is only 6 per cent loss in the motor and generator, including the bearings and the windage, so that 14 per cent for an electrical transmission on a large scale is a little strong.

The comparisons of the Jupiter and Cyclops have been brought up. The questions which this gentleman has asked I also asked the Department to explain to me when I was getting material for the paper, but I did not get any more satisfactory reply than he did. A comparison of that sort, based on some reports of coal consumption, is not a comparison at all. It may be affected by many conditions. In point of fact, the comparison between the Jupiter and Cyclops as shown in the paper of Lieutenant Robinson has an opposite characteristic from that which you would expect. It shows the ships coming nearer together as they go to heavier loads, and a large advantage of the Jupiter at light loads as against the Cyclops at light loads. The probability is, if you had a true comparison, you would find that the curves, instead of converging, would separate as the load went up. How they stand in relation to each other is something we cannot prove.

I will later touch on the subject of the relation of turbines to reciprocating engines, but will pass that for the moment.

As to the question of the propellers on the Jupiter and Cyclops, the record of indicated horse-power to shaft horse-power measured shows an advantage from the Jupiter's propellers. When the Jupiter's propellers were designed I sent a drawing of the propellers, which I received from Washington, to Philadelphia to Mr. Metten, and asked him how they compared with the Cyclops propellers and how he thought the efficiency would compare. He said he thought the propeller was a very good one and it was almost equivalent in design to that of the Cyclops, but, since it ran at a speed something higher than that of the Cyclops —something like 12 per cent—he thought the efficiency would be 1 or 2 per cent worse than the efficiency of the Cyclops propeller. I think probably the Jupiter does show a better propeller efficiency, and that it is largely due to the fact that when the Jupiter's trials were run she was in quite a seaway and her propellers were held at an absolutely constant speed going into the water and out of it again without shock, and with a perfectly uniform rotative effort I should consider that condition favorable to the propeller.

I think it will be shown in geared ships that the same advantage will be accomplished. When they come to run big, slow-speed propellers, with steady rotation, they will be surprised at the results obtained. I have studied the torque diagrams of engines somewhat in connection with the running of alternators in parallel and in connection with various electrical problems, and there are quite big variations. These variations in speed, if applied to the grip of the propeller blade on the water, must affect it. There must be a great advantage in a propeller which does not race, which rises to the surface of the water without change

of speed. There seems, therefore, to be a possibility that some of the propeller advantage may be in the drive after all.

Something has been said about the size of casing. I will say that I think the casing which covers the movable part of the California's turbine is smaller than any casing talked about here this afternoon, so we are not very much at a disadvantage in that respect. If you will look at the plates, you will see that the turbine of the California, as shown there, consists of a high-pressure end and an exhaust end. The part which lifts does not include the exhaust end, which connects to the condenser. The hood which connects to the condenser on this part is empty, and when the other part of the turbine casing, as shown, is lifted, the whole thing is in your hands.

There need be no speculation as to the economy of the Jupiter, for the reason that her turbine was tested in Schenectady delivering power to a water box—it was inspected by the government engineers while it was being tested. Its water rate, under the conditions specified, was accurately determined with a various degree of superheat and pressure, at various speeds, and at loads which exactly correspond to those at which it operates when running the ship. In the tests on the ship the water was measured by carefully calibrated tanks, and while in running the auxiliaries were not measured, the same condition was created in the operation of auxiliaries with main unit not running, and the measurement of the water used by the auxiliaries was taken. These water rates stated in the report of the trials of the Jupiter are corrected for the separately measured water consumption of the auxiliaries.

Then there were certain corrections due to the fact that there was moisture coming over from the boilers with the steam. There was also a difference of vacuum and a considerable discrepancy in steam pressure from the conditions specified. When duly corrected for these differences, these curves of the test of the Jupiter's turbine, made in her final trials, agree exactly with those made in Schenectady.

Furthermore, the result is nothing phenomenal or unusual, because I can show you twenty turbine tests which agree with it exactly and which, with normal electrical apparatus, will give just such results as are shown on the Jupiter.

As for the tests on the California, there are several turbines operating right in this city which, if put into the California, would give better results than those which I have shown. They might not be exactly suited to the case, but if you made room for them and ran them you would get the water rate.

The question has been brought up as to the relative economy of turbines and reciprocating engines on shipboard. That is a very hard thing to get at. You can get at lots of comparisons of the character which have been made here, as to the records of the water consumption of some ship, or how much coal she burned, but when it gets down to measuring the water rate and measuring the power delivered to the propeller, the marine engineers have not done it. I have searched diligently to find this comparison, but the only just comparison I have secured has been obtained from Sir Charles Parsons. He has been in exactly the same situation as I have; he wanted to convince the world he had something that was of advantage. In connection with his geared ships, he has made certain comparisons—I dare say he has more now, maybe, than these I have, but they are very good and interesting. In the first place, in his original ship, the Vespasian, he had her engines in good order, ran a voyage, investigated exactly what the auxiliary used, and found out what the main engine used by means of water measurements and the indicator. He then put his geared

turbines in the Vespasian and by test with torsion meter showed much improvement. He put her under similar conditions of trim and showed a definite comparison.

Then Sir Charles Parsons made another determination. That is, he took a ship called the Cairngowan, an engine-driven ship, and tested her in comparison with the Cairnross, a turbine-driven ship, similar propeller speed, a sister ship and identical in all respects. The comparison as published would lead us to believe that these tests are comparable. These ships are something like 1,700 or 1,800 horse-power. The Cairngowan used for all purposes 17.3 pounds per shaft horse-power. Under similar conditions the Cairnross used 14 pounds. The steam consumption of the Jupiter, under exactly the same conditions as the Cairngowan, would be 11.97 pounds; that is, against 17.3 on this engine-driven ship. This is the only comparison that I know which is a just one, made properly.

It is extremely hard to test water rates of apparatus. You must have all the facilities and everything absolutely right and be able to get consistent results, over and over again, to be sure that you are right. Of course, in Schenectady we have done more of that in our work than has been done anywhere else in the world; we have been developing the art of prime movers so very rapidly that we have needed immense facilities for testing. The Jupiter's turbine was put right on a condenser, the degrees of vacuum produced, the output of electrical energy was exactly measured, and everything determined in the most scientific manner, so that there can be no question at all about the results.

The question of the maximum speed of the California is another matter concerning which I am not informed. We were required under the specifications to make guarantees of speed and very heavy penalties under certain test conditions, and one of these test conditions was the highest speed which the ship could produce. In another part of our specifications we were required to furnish 25 per cent more power than the ship was supposed to require at a certain speed, 21 knots. That, as I understood it, required us to furnish 36,400 horse-power to the propellers of the California and to produce this guaranteed water rate at that maximum output. As I understand it, the government is at liberty to run that ship as fast as it can and penalize us if our water rate goes above that point. We have had to make our curve turn up a good deal at the maximum to take care of that very extreme condition.

Now, as to the question of the California's propeller efficiencies which has been raised, I can give no information. I simply have stated what Captain Dyson has told me, that our speeds are advantageous and there is a certain gain. As to the actual comparison made here, I cannot exactly blame him for it—it is the result of certain information obtained largely through him, and it is approximately in accordance with a certain curve which he sent me, giving the possibilities of different speeds of propellers and different numbers of propellers in this ship and certain other ships. It may be right or wrong, but there is certainly a considerable advantage in these lower speeds.

The President:—I am sure we are all much indebted to Mr. Emmet for his interesting paper. I will mention that Paper No. 6, which is on the program for today, will be postponed until tomorrow morning. Paper No. 12, on the program for tomorrow afternoon, will be read in the morning.

THIRD SESSION.

FRIDAY MORNING, NOVEMBER 19, 1915.

Vice-President Washington L. Capps called the meeting to order at 10.30 o'clock.

THE CHAIRMAN:—Our President was with us a few moments ago, but having been called away for a short season, has asked me temporarily to take his place. We will begin the program this morning by the presentation of Paper No. 8, entitled "Interior Decoration of Vessels," by Mr. Harry B. Etter, Associate. The paper will be presented by Prof. W. Selkirk Owen, Member.

PROF. W. SELKIRK OWEN, *Member:*—In the absence of Mr. Etter, I have been called upon to submit a synopsis of this paper.

INTERIOR DECORATION OF VESSELS.

By Harry B. Etter, Esq., Associate.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

As civilization grows older, we become more refined in our modes of living—it is necessary to have our surroundings pleasant to the eye and thereby restful to the mind. This education has been going steadily on until to-day we take great pride in having things in our own homes correct as to line and color as well as for comfort and utility. The time has passed, let us hope for ever, when any old thing for wall covering or any article of furniture was placed in our homes without any regard as to combination of color or period of decoration, just because it answered the purpose of use.

So much for our permanent home. How about our temporary home? If we wish to stop at a hotel, it must be a fine one or it is passed by for one that is fine. We travel on land by Pullman car where we usually have beautiful scenery to gaze at from the window to amuse us. But the ship is a somewhat different proposition. We tire in time of looking at the sea after the shores have faded in the distance, so we must turn to her. The comfort and beauty of her interior must take the place of mountain, river and distant hills.

I have heard it said, "Oh, who ever looks at it? Not one in a hundred;" when it is more than likely the other way about—one in a hundred who do not notice it. Utility is not the only thing to be considered, for a barn-like appearance soon palls on even the most crude.

The traveling public of to-day demand and are willing to pay for pleasant surroundings and comfort whether by land or sea. True they get it on most of the trans-ocean liners, but with the American coast-wise steamers, with some notable exceptions, they are not so fortunate. I do not wish to criticize these steamers too harshly, but they are for the most part ugly from a decorative standpoint. The writer has been on board of some of them where the interior was an eyesore, when a really fine effect could have been made for a very little if any additional cost. The joiner work has to be made to suit the vessel, and it could just as well have been made to follow some good design instead of a riot of meaningless panels, mouldings and pilasters. The joiner work of most of these vessels is very often of the same design from end to end, bottom to top, and bad proportion at that. It must be trying to one of refined taste to have the same thing staring at him every place he goes for a week or so.

It seems to be a mistake when a new passenger vessel is to be built if some scheme of decoration is not worked out. Of course this has been done for some of

them with notable success and things seem to be improving in this respect. There are so many periods of decorative styles so suitable to be selected from for a vessel's interior, most of them not expensive to reproduce, that it seems anything else should be discarded.

In working out a successful design for an interior a great many things should be considered, and care should be exercised not to have the decoration of adjoining public rooms so one will shock the other. All should blend together like one complete thing and yet not be alike. Other things to be considered are: First always, meaning; followed by balance of line, light and shade, repetition, variety of surface, choice of material, contrast and harmony of color and suitability for the trade the vessel is to engage in.

Exquisite form and proportion must be gained by extreme simplicity of beauty of line in the division of a wall surface into a series of panels, borders and mouldings, separated by pilasters, columns and other architectural forms.

Simple designs well proportioned are an attraction in themselves, and an excess of elaboration should be carefully avoided. Mixture of styles does not always secure the best results. Ornaments, if used, should not attract the eye to the exclusion of the background as if it were an entirely separate part, but should be subservient to the general effect.

Furniture, upholstering, draperies, etc., should be carefully selected to harmonize with the style of the room. Too often is this neglected and a truly beautiful room spoiled by unsuitable furnishings. The designer of the decoration, if he knows his profession, can be and should be consulted in regard to all details, as he can picture in his mind what such things should be as he progresses with his work.

The interior decoration of a vessel is very often unsuited for the climate she is to trade in. The writer was once called upon to look over a steamer engaged in tropical service to see what could be done to improve her. I found the smoking room "a Black Hole"—everything dark, gloomy and hot looking. The other public rooms were not much better—mahogany everywhere. Why is it so many shipowners insist on mahogany or oak-panelled walls when we can get so much better results from delicate tints? In the first place hardwood walls kill the furniture; they absorb the artificial light also, for no matter how brilliantly a vessel may be lighted there are always deep shadows and dark corners. Light colors are cheerful; they reflect the artificial light and make a good setting for rich furniture besides. Of course there are cases where light tints would not answer. A smoking room, as we all know, would not do to be decorated like a ball room, yet we need not have it dark and gloomy like the vessel just referred to.

While we do not want dark, hot-looking rooms for tropical climates, but something cool and airy, just the reverse may be said for vessels engaged in the colder regions. Here we want to feel warm and comfortable. A theater which I occasionally visit is decorated in light green and French white in stiff Grecian style. For appearance nothing could be more inappropriate. It gives one a chill on a cold

night, but might be pleasant on a warm one; however, the house is not open during the summer months.

If a period of decoration is to be adopted we should stick to it not only in line but in colors and material, both woods and woven goods, and not fly off in the middle of it to suit some individual taste. The writer once saw a set of specifications where a certain room was to be panelled in oak in Adams style, as if such a thing were possible. We can use oak for a great many things, but never in Adams period, to be correct.

Some of the periods of decoration which are most pleasing and well adapted for ship interiors are Louis Quatorze, Regency, Louis Quinze, Louis Seize, French Empire, Elizabethian, The Georgian periods, Adams, American Colonial and some others not so well known by those who are not connoisseurs of art. Some of the Italian styles are beautiful and are especially suited for first class yacht work, as they are fine as to detail, mostly always carved and consequently more costly.

Of the different periods of decoration a few remarks may be interesting. The classic styles of the Greeks and Romans would, if strictly carried out, be too massive and stiff for ship decoration. With the Renaissance, architecture had a new birth. When the world did not come to an end after one thousand years of the Christian era, as had been predicted, men began to take heart and live again and by the middle of the fifteenth century the Renaissance was well on its way. This condition soon spread throughout Europe, and nearly everything in architecture we see of the present age is based on the Renaissance period.

Of the French periods, Louis Quatorze, somewhat severe of line, shows a softening with the Regency, followed by the gay and elaborate period of Louis Quinze "The Well-loved," where the flowing rococo suggests music, laughter and frivolity. With Louis Seize comes a period of perhaps the most interesting and beautiful of all the French styles. While the beautiful and frivolous young Queen Marie Antoinette had great influence, yet this period has more meaning and better balance of design than the preceding periods. The French Empire, the style of Napoleon, with its Egyptian and Roman ornaments, has not the magnificent grandeur of the preceding periods, yet it is rich and dignified.

The styles in England after the Tudor or Elizabethian period closely followed the French as to general line. The three Georgian and Adams periods are very dear to the American heart, for here we see the inspiration of our own so-called American Colonial—the style of our forefathers, stately, yet with that quiet repose the more fanciful French styles lack.

As smoking rooms are mostly always finished in oak, some of the sixteenth century English or Flemish styles always look well and make an agreeable change from the lighter and gayer styles employed for a music room or lounge. For outside rooms such as a veranda or enclosed promenade deck, palm room and the like, a garden effect with trelliage panels can hardly be improved upon. Stateroom corridors and alcove passages as plain as possible are better than a lot of small

panels and fancy mouldings. The best example of stateroom corridor I have ever seen was on the Cunard line steamer Aquitania. Here panels were eliminated entirely. The walls were built of tongued and grooved planks finished smooth and covered with a light canvas stretched on and painted, with pilasters at doors and corners only. They looked very neat and were doubtless much cheaper to build and keep in good order than panelled walls. Stateroom division bulkheads, if also built this way, would make all four walls alike in the room. Panels never work in well around berths and other numerous stateroom fittings. There are some of the suites on the Aquitania where these walls are papered like the rooms of a house and they look very nice, with a mezzo-tint print or other good picture hung here and there. When soiled this can easily be renewed, besides making the room homelike and a good setting for the furniture.

The dead white enameled walls of the average stateroom are too glaring. The walls back of the corridor and alcove bulkheads usually show the back of the panels of the opposite side, and with the division walls of the usual tongued and grooved stuff make all four walls different and are very unsightly. The flush walls mentioned above would prevent this.

These remarks are merely suggestions. It is not necessary to have English or Flemish Renaissance because it is a smoking room or trelliage because it is an outside room, etc. There are many varieties to select from, or a good decorator can work up a design that may be original and interesting, yet at the same time mean something.

We do not need to have carving or ornaments to make a thing attractive. To begin with, carving is a dirt collector, and unless one can afford to have it well executed it had better not be attempted. The H. P. Whitney yacht—at the time of writing this paper building at Cramp's—it would be well to mention, is entirely devoid of carving or ornament, everything depending on the simple lines of the panel work which, together with the beauty of the woods used, the hardware, lighting fixtures and furnishings of every kind to correspond, is going to be very much of a success for a vessel of her type. I have often wondered why in yacht work, when smallness of space usually requires joiner work to be as flat as possible, marquetry is not used more. Here we usually have hardwood walls, mahogany or walnut, and a beautiful effect can be had with large, flat panels with a narrow border of satinwood, maple or some other silky grained wood inlaid an inch or so from the edge, set off with the straight lines of Sheraton or Hipplewhite furniture which is usually inlaid. The ceilings of such a room could be a light tint harmonizing with the inlay, contrasting the dark wood and lightening it up.

As the discussion of the many different styles of decoration is so very extensive that it could not be taken up within the limits of this paper, I have only attempted here a few remarks to try to increase interest in that direction. It has always been the writer's opinion that the ship look of a passenger vessel should stop upon the entrance to her interior, and be intended to appeal to people used to living on shore.

Proportion is another great consideration. As the deck heights are usually too low for the size of the room, the walls should be designed to deceive this and give the impression of height. This can be greatly improved by keeping the chair rail, if there be one, as low down as possible, thereby making the upper panels the longest and preventing the squatty look. Columns and pilasters should be well proportioned and with caps and bases suitable for the shafts. It costs no more to turn a column shaft to the proper diameter in proportion to the height and to have the proper taper and fluting, than one poorly proportioned. There are a number of books that treat of this subject, of which Vignola is considered the best.

Cornices and mouldings should have a defined profile. You often see a jumble of curves and fillets with no particular meaning and cornices too deep or with too much projection or else too little for the lower portion of the wall. Neither should they be too intricate, for, as it often happens, the forecastle hands may have to paint her some time and they are more inclined to finish quickly and leave no "holidays" than to make a careful job, so pile the paint on thick which soon clogs the mouldings and spoil their beauty. The bed mouldings of cornices can be enriched if more elaboration is desired. Egg moulding, dentil courses and the like are rich, pleasing, and good taste, and, as they are inverted, do not collect dust. These, however, should be well above the eye line to have a good effect.

Panels should be large and, when made of several ply wood or one of the many kinds of composition, will not warp or crack. Small panels or those running in a brick fashion have a gingerbread look and require more labor to put together, which adds to the cost and lacks appearance.

If a hung type of ceiling be employed, that is, one framed under the deck beams, it should be carefully treated. Here we usually have a large unbroken area and a fine effect can be had with some elaboration by enriched mouldings and ornament, which, if well executed, adds so much to the beauty of the room and is always interesting from any point of view. Hardwood panelled ceilings are happily becoming a thing of the past and those of an ornamental plaster effect, corresponding of course with the style of architecture of the room, a vast improvement. The more common way of casing in the beams and forming panels between them, which for some styles would answer very well, are usually too heavy. The steel deck beams are generally too large and spaced too close together for proper architectural proportion, and, besides, it happens at times that where a steel beam has to be reversed for structural purposes, they cause an unequal width of the panels.

DIFFICULTIES.

There are many difficulties to be dealt with in interior ship decoration, caused by the shape of the vessel, the structure, the crown of the decks, the sheer, the low deck heights and the smallness of the air-ports and deck-house windows.

The shape of the vessel necessarily has to stand, as well as the structure for

the most part. But here many of the difficulties caused by the structure could be avoided if those in charge of the structure and decoration would work together and a little flexibility exercised together with a little judicious scheming. Stanchions, girder lines and web frames can almost always be placed to suit architectural requirements without sacrificing the strength of the vessel.

One of the greatest difficulties to a good architectural effect is the crown of the deck. This does not add to the strength of a steel vessel, and, except for the weather deck or a deck affected by freeboard regulations, could be made flat. In fact, the weather deck of the American line steamers St. Louis and St. Paul was made flat, but is the only case I ever remember seeing. This crowning of the decks prevents horizontal lines so important to architecture and spoils many good architectural details if they happen to come off the center line.

The sheer of the deck can hardly be avoided in most vessels, and, not being so severe as the crown, does not do so much harm to the design.

The low deck heights, being all out of proportion to the size of the average room, are hard to treat and require resourcefulness unless the public rooms are under the boat deck. The writer had the good fortune, when about to design the interior of the steamers Great Northern and Northern Pacific, recently built by Wm. Cramp & Sons, to have also worked out the preliminary arrangement of these vessels, and was enabled to form in mind at the same time the scheme of interior decoration which made it much easier to carry to a conclusion than if several persons were engaged at different times for the different parts.

In these vessels the public rooms except the dining saloon were all on the promenade deck, and, by following the type set forth by most foreign-built liners of carrying the deck-houses above the level of the boat deck, we had a good proportionate height in comparison to the size of the room. The dining saloon, which was on a lower deck within the hull, was made 10 feet high by making this the deck height throughout the length of the vessel. This height answered very well, considering that this room was a very large one.

As these vessels were treated throughout, except the smoking room, in the Colonial style I was enabled to have fanlights over doors and windows, arches and other details so characteristic to this period of design. The lofty appearance of these rooms was greatly improved by placing the chair rails as low as 30 inches above the floor, making the upper panels of good length.

That ship decorators appreciate more height to a room on shipboard is shown as far back as the steamers City of New York and City of Paris, now the New York and Philadelphia of the American Line. The dome over the dining saloon of these steamers was the beginning of a new era and has been followed out with many improvements ever since. On some of the large liners built abroad in recent years we find some of the public rooms carried up two deck heights. Of course this takes up valuable space that could be used for staterooms, and, unless the vessel is a very large one, could hardly be afforded by most owners.

Most of the Long Island Sound and Hudson River steamers have had the

large central well as far back as one can remember. The walls were always treated alike on the several decks in view, which spoiled the effect. In the steamer Commonwealth great improvement was made in treating the two heights in the Venetian Gothic saloon more like one height.

If the deck heights will permit it, a good practice is to hang the ceiling under the beams before mentioned, with large panels and false beams to suit the design of the room. With the hung ceiling it is possible to carry ventilation ducts, pipes, electric wiring, etc., above it and out of sight, to which access can be had where desired by having some of the panels made so that they can be taken down without disturbing the remainder of the work. With a ceiling of this type it can be better treated to suit the period of design chosen for the room and will also serve better to reflect electric lighting by avoiding the deep shadows between the beams.

Airports and deckhouse windows by the smallness of the openings usually form a problem hard to treat. The inside sash sometimes employed helps matters a great deal. This method was used in the dining saloon of the Great Northern and Northern Pacific, the sashes behind the airports being glazed in a glass known as satin finish which broke the outlines of the airport and gave the effect of large colonial windows. Of course it has to be admitted that when the sashes have to be opened the good effect is somewhat lost and the draperies have then to make up for it. The promenade deck of these vessels was enclosed for the length of the main public rooms and large house type windows were used for those rooms. But we are not often so fortunate as on the steamers mentioned and have to use other schemes. Ports and windows, if worked in pairs, can be treated as a large double window and look better than if spaced singly and equally distanced all around the walls as so often seen. On the Whitney yacht before mentioned, very large plate glass windows are introduced in the deck-houses. These large windows are arranged to suit the interior of the rooms and are a very great improvement over the pigeon-hole type more often used. This yacht, it may be well to remark, is one of the cases where the decorator and the constructor have had to work together from the beginning.

With the height of large steamers above the water it is possible to employ large metal-framed windows especially designed to suit the interior. This is being done on most of the transatlantic lines with great success when the location is not too much exposed to the elements.

Too much care cannot be taken in working out the staircases. The stairs in most vessels are too steep and winding. Winding stairs only look attractive on a plan. Thwartship flights should be avoided as much as possible, as in descending such flights one has to meet the rolling motion of the vessel.

The proportion of the width of tread to the height of the riser should be carefully worked out. A good rule is to have the sum in inches of one tread and two risers to equal as near as possible to 24 inches, the width of the tread taken always without the nosing. A good proportion would be 7 inches for the risers and 10 inches for the tread. While a less angle of incline would perhaps make a grander

appearance, in no case should the tread be more than 12 inches wide or the risers less than 6 inches high.

As the staircase in most vessels is generally a principal feature, care should be taken to have it of a good design with balusters or grille railing corresponding to the design of the surrounding joiner work.

Built-in seats for public rooms are abominable. They are generally uncomfortable to sit upon by not having the proper arm rests and should be done away with where comfort is desired, and chairs of the lounging type substituted. Then, too, in case of damage it is cheaper to renew a chair than a long cushion seat. Chairs and settees corresponding to the style of the room also add to the fine effect.

Painting for period design always looks much better flat finish or at the most a slight egg-shell gloss. Very glossy surfaces throw off glints of high light that is very trying to the eyes. Too many colors should be avoided. The different shades of a color show the better taste.

As artificial lighting has more than ever become a strong decorative feature since the advent of electric lighting, a few remarks made here would not be out of place. Soft lighting effects are the cry of the present age and the light bulbs if covered with globes of the many artistic designs manufactured (keeping in mind, of course, the style of the room), will produce this effect. As a vessel's saloons are rarely high enough to successfully have indirect lighting, the wall bracket can be used to a great advantage. The wall brackets, properly designed, have a rich effect and work in well with most architectural designs and are not hidden behind beams and girders, producing shadows like ceiling lights would, that is, when the ceiling is not hung or made flush.

When ornamental glass panels are fitted at the ceiling level of skylights or in dome skylights, the lighting of the room is always greatly improved if lights are fitted behind them. Otherwise the skylight makes a black patch at night and puts the whole middle of the room in shadow. The writer believes that the light should come from the same direction by night as by day.

In presenting this paper to the Society, the writer does not wish it to be understood that he has especially taken the American coastwise steamers to task to unduly criticize them. Many of the steamers have cost a good sum to build and cater to a representative class of travelers. I only wish to show what could be accomplished by a little forethought and a comprehensive working out of the plan at the start. It is usually too late to work out a good decorative scheme after the vessel is half built, but it should be taken in hand at the very beginning and the decorative design of the different rooms worked out along with the structure of the vessel. This will often prevent a door here or a window or column somewhere else that will spoil the balance of the design when it could just as well have been placed to suit the architectural effect had it been taken up in time.

It is to be regretted that in this country so few really fine passenger vessels are built, when a correct artistic interior is demanded, that a firm of decorators

specializing in ship work like they have in Europe could hardly exist. These firms not only design but build and furnish the interiors complete. House architects or decorators are sometimes called upon in this country when some special ship work is to be done. While they make a fair showing considering that the work on shipboard is new to them, yet the conditions are so entirely different from those they meet with in buildings on shore that they must first learn something about ship construction in order to keep out of trouble.

With the upbuilding of the American merchant marine, if that good day is about to arrive, let up hope that the conditions will so improve that we can turn out a vessel second to none from an artistic as well as from a mechanical viewpoint.

The comfort and beauty of the interior of a passenger vessel are, after all, the main attraction to the traveler, the same as such things are in a hotel to the guests or in a clubhouse to the members where nothing is spared to make them a success. Why, then, cannot the same care be taken with the ship? I thoroughly believe it would be appreciated.

EXPLANATION OF PLATES.

Plate 43.—S. S. Great Northern. Dining Saloon Showing Hung Ceiling and Air Ports Hidden behind Sashes.

Plate 44.—S. S. Great Northern. Lounge. We Can Appreciate Here the Good Deck Height Made by Carrying the Top of the House above the Boat Deck. The Large House-type Windows Can Also Be Seen.

Plate 45.—S. S. Great Northern. Smoking Room. The Dome Is Illuminated at Night, Throwing a Soft Light into the Room.

Plate 46.—Steamer Commonwealth. Venetian Gothic Saloon. This View Shows the Treatment like one Height of the Saloon and the Gallery Decks.

Plate 47.—S. S. Great Northern. Stairs at Writing Room Level Showing the Flights Running in a Fore-and-aft Direction.

Plate 48.—S. S. Great Northern. Head of Stairs at the Promenade Deck Entrance. The French Type Doors to the Balcony at the Head of the Stairs Open into the Observation Room, Making an Agreeable Change from the Usual Mirror.

Plate 49.—S. S. Great Northern. Observation Room. The Good Deck Height Is Shown as Well as the Large Windows and Bay Breaking the Monotony of a Rectangular Room.

DISCUSSION.

THE CHAIRMAN:—Gentlemen, you have heard the abstract of Mr. Etter's paper as presented by Professor Owen. Much of the matter brought together in this paper has undoubtedly come to the minds of those who have had to deal with the design and inte-

rior decoration of vessels. The Chair would be very much pleased to hear from any of the members present their views upon this subject. It would seem that if there are many owners here who have had to bear the criticism of vessels owned by them, and have experienced certain feelings of regret at having to pay bills for decorations which did not suit their purposes, we will doubtless have discussion. This is an interesting paper, and brings up incidentally questions which are vital to the seaworthiness of the vessel, and which have a good deal to do with the comfort of the men on the vessel. Incidentally, the things that cost the most are not always either the most efficient or the most pleasing. It is quite within the memory of many of us here that not very many years ago we used a great deal of joiner work in vessels of the Navy in order to hide, as much as practicable, many structural features of the vessel. We have long since abandoned that practice, with great benefit to the vessel itself and without offending the æsthetic sense of those who had to live on board, I am quite sure.

Does any member desire to discuss this paper? (Pause.) In the absence of discussion, we will pass to the next paper, No. 6, entitled, "Results of Model Tank Experiments to Determine the Action of a Ship Brake," by Capt. Wm. Strother Smith, U. S. N., Member, which paper, due to the unavoidable absence of the author yesterday, was deferred until today. The paper embodies the results of some model tank experiments.

Captain Smith presented the paper.

RESULTS OF MODEL TANK EXPERIMENTS TO DETERMINE THE ACTION OF A SHIP BRAKE.

By Captain Wm. Strother Smith, U. S. N., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

This paper is presented with the idea of showing the interesting data obtained in the model tank at the Navy Yard, Washington, for use in determining whether or not it was feasible to design and install a brake on the side of a merchant vessel to assist in stopping a steamer when in danger of collision or grounding.

The question of installing such a brake is a financial one and is dependent upon the lessened insurance demanded and the advertisement of such an appliance to increase the passenger list.

This question is not one for the naval architect or marine engineer to solve and is not brought up for discussion on that point.

In the spring of 1910, a set of trials was made on the U. S. S. Indiana off Delaware Breakwater to determine the effect of the Lacoste ship brake. Due to a lack of preliminary investigation, this trial showed very little either for or against the brake and it was some time after that the writer was requested by personal friends to take up the study with a view to designing a practical brake.

After the loss of the Titanic interest was awakened to such an extent that a syndicate was formed and the permission of the Navy Department was obtained to make a series of trials in the model tank, and the results of these trials are now presented to you through the courtesy of the Lacoste Shipbrake Syndicate.

The Wm. Cramp & Sons Ship and Engine Building Company was kind enough to furnish the lines of the S. S. St. Louis, and a model of this vessel was constructed.

Three runs (Nos. 1, 2 and 3) were made to determine the curve of speed and power before fitting any brakes, and the successive ten runs were made with different areas and settings of the brake to determine the resistances and pressures per square foot.

The S. S. St. Louis is 536 feet in length, 62 feet 9 inches beam, and the draught at load line was 28 feet for model experiments, the displacement being about 17,230 tons.

Plate 51 shows the curves of speed and effective horse-power as determined under the following conditions:—

Runs 1, 2 and 3 show the speed and power curve without brakes. The succeeding runs were with brakes as stated.

Runs 4 and 5—brakes, 12 feet 2¼ inches by 14 feet at 80°.

Runs 6 and 7—brakes, 12 feet by 14 feet at 90°.

Run 8—brakes, 12 feet by 14 feet at frame 76, and another pair 8 feet by 18 feet at frame 95, set at 90°.

Run 9—brakes, 10 feet by 14 feet at 90°.

Run 10—brakes, 8 feet by 14 feet at 90°.

Run 11—brakes, 8 feet by 14 feet at 70°.

Run 12—brakes, 12 feet by 13 feet with the top edge placed one foot below the water line. All other runs were made with the top edge at the water line.

Run 13—brake, 8 feet by 21 feet at 80°.

Plate 52 shows the pressures per square foot on the brakes as indicated on the plate by the runs numbered.

The following deductions are made:—

The stopping power varies directly as the projected area opposed at 90° to the fore-and-aft line.

One pair of brakes is more efficient than two, as shown by run No. 8, where the combined area is 624 square feet for the two brakes, the stopping power or resistance opposed is not in the same proportion as the pair of 12 feet by 14 feet, giving 168 square feet.

The pressure per square foot practically decreases as the width of the brake is reduced and, by plotting curves of pressures at various speeds for different widths of brake, it is found that after a certain width is passed the pressure per square foot is not increased.

After these curves were determined, the model was fitted with a pair of brakes 11 feet 8¾ inches (projected area) by 14 feet deep, fitted so as to be tripped and thrown out from the traveling carriage of the model tank. A set of guides was fitted so as to keep the model in position under the carriage, yet allow it to advance freely when the carriage was stopped.

The foot-way along the tank was marked off in equal distances from a certain point far enough from the starting point to allow the carriage to reach the proper speeds. The model was then brought up to speed, the carriage stopped at the determined point, the model released with the brakes thrown out, and the times marked by stop-watches at each marked distance until the model was brought to rest or the limit of the tank reached.

For each speed the model was released with the brakes closed, so a comparison was obtained and shown on Plate 53 of speed reduction per foot traveled and on Plate 54 the speed reduction per second traveled.

As a matter of interesting data, the following table showing the instantaneous stopping effect of a pair of brakes of different sizes has been compiled from the curves shown on Plate 51:—

Size of brake.		Stopping effect at various speeds in effective horse-power speeds.								
Wide.	Deep.	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
12′	14′	13,000	15,500	18,250	21,750	23,250	28,500	32,200	35,250	38,500
10′	14′	10,600	12,750	15,000	17,500	20,000	22,500	25,600	28,300	30,400
8′	14′	7,850	9,500	11,250	13,500	15,500	17,500	19,800	21,900	24,000
6′	14′	5,300	6,400	7,590	9,100	10,460	11,810	13,360	14,780	16,200
12′	13′	11,800	14,100	16,600	19,800	21,100	25,900	29.300	32,000	35,000
10′	13′	9,600	11,600	13,600	15,900	18,000	20,400	23,300	25,750	27,660
8′	13′	7,100	8,600	10,200	12,250	14,100	15,900	18,000	19,900	21,800
6′	13′	4,650	5,650	7,650	8,250	9,500	10,700	12,100	13,400	14,700
10′	12′	8,600	10,400	12,300	14,300	16,000	18,300	20,900	23,175	24,880
8′	12′	6,300	7,700	9,100	11,000	12,600	14,300	16,000	17,900	19,600
6′	12′	3,900	5,050	6,850	7,400	8,500	9,600	10,800	12,000	13,200
10′	10′	7,000	8,600	10,100	11,900	13,300	15,200	17,000	19,300	20,700
8′	10′	5,200	6,400	7,500	9,000	10,400	11,800	13,100	14,500	16,200
6′	10′	3,100	4,100	5,600	6,100	7,000	8,000	10,100	12,000	13,200
8′	8′	4,100	5,100	5,800	7,000	8,300	9,400	10,400	11,500	12,000
6′	8′	2,400	3,200	4,300	4,700	6,500	7,400	8,200	9,000	9,500
6′	6′	1,700	2,200	3,000	3,200	4,600	5,400	6,000	6,600	7,000

Using a pair of brakes 11.73 feet wide and 14 feet deep set normal to the direction of the vessel, the speed being 18 knots, the speed will be reduced to 15.2 knots in 500 feet, to 11.6 knots in 1,000 feet, to 7.15 knots in 2,000 feet without the assistance of the propellers in backing.

Assuming the weight of the vessel at 17,230 tons, the striking blow at

18 knots equals 247,300 foot-second tons.
15.2 knots equals 176,300 foot-second tons.
11.6 knots equals 102,700 foot-second tons.
7.15 knots equals 39,000 foot-second tons.

Using the element of time, the speed will be reduced in

50 seconds to 11.1 knots.
100 seconds to 7.35 knots.
150 seconds to 5.85 knots.
200 seconds to 4.70 knots.

The experiments conducted on the U. S. S. Indiana showed very little. The vessel was entirely unsuitable, owing to the fact that there is not a straight line in

any part of her hull and the brake had to be fitted on by means of a molded frame. There were no accurate means of determining the total instantaneous indicated horse-power nor the exact speed.

When the subject was revised, the model tank was considered by far the most accurate method of determining the data to be used in designating a brake. To satisfy the ideas of many concerned, various forms of the brake were considered, principally with the idea of controlling the brake by power so as to open and close at will, the vessel going at full speed.

Scheme 1.—Long hydraulic cylinders installed athwartship on a stiffened bulkhead to work connecting rods attached to the brakes. This involved an additional weight of about 190 tons, including 33 tons of contained water.

Scheme 2.—In order to reduce weights, especially that of contained water, a toggle joint arrangement was studied to reduce the power required and to reduce the peak load when the brakes were to be started in. This involved a stress of 340,000 pounds on each of three principal connecting rods and 320,000 pounds on each of three lesser members.

Scheme 3.—Rack and pinion arrangement, allowing very little contained water. The diameter of the vertical shaft working the pinions and the width of the gear needed rendered this scheme out of consideration.

Scheme 4.—Same as Scheme 3, but with the idea of pushing the brake out to 35° to assist the rudder. This required too much machinery to develop the power necessary, about 500 estimated horse-power for a pair of brakes 9 by 13 feet.

Many other schemes were studied out, but the weights and power required made any and all of them impracticable.

The final conclusion reached—that the simplest form of brake designed to be set in the side of a vessel, to be released instantly by the officer on the bridge by throwing a lever and open by the pressure of the water without further thought; to be supplied with only enough power and mechanism to haul in the brake when the vessel was stopped or going astern and lock it fast for future use—was the only practical solution of the question.

With these points in view, a type design was made for the Canadian Pacific S. S. Empress of Asia, practical, strong and simple, for emergency use only. The officer on the bridge has but to pull a lever and the brake will open and exert its resistance. When the danger is past, it requires but the attention of one man on each side to haul in and secure the brake.

With this done, the technicist closes his work and the financier and promoter begins to write his story.

DISCUSSION.

THE CHAIRMAN:—This interesting paper by Captain Smith is now open for discussion.

MR. CLAY L. JENNISON, *Junior*:—As I am a Junior Member and have only recently been elected, I do not know that I shall be allowed the floor. In some recent tests in the model basin in Washington, which I conducted for Mr. Hyde, of Tacoma, Washington, I found the results—although they were rather elementary compared with what Captain Smith has offered—compared very favorably with his results. In tests on the midship section we fitted a series of brakes in place of one or two. We found that the results obtained were very unfavorable, but on results from brakes fitted well forward, so that they obtained a good flow of water, we received an increase of resistance of about 300 per cent. That seems almost abnormal, but the curves show it at 13 knots.

Recently Mr. Hyde has had tested some brakes made up of sections of the bilge keel; the sections were about 6 feet long by about 2 feet in section. These showed a resistance increase of about 155 per cent. From these results and the ones we obtained previously, Mr. Hyde has decided to go ahead with some work on his own plans, and I think in the near future a vessel on the west coast will be fitted with brakes, either the bow brake or bilge keel brake. Perhaps at an early date Mr. Hyde will be able to submit to the members of the Society some data on the bilge keel brake.

Further, I would like to ask Captain Smith a question. In his paper he says that some brakes were made for the Empress of Asia. I would ask if these have been placed on the vessel, or if they are going to be placed on the vessel?

CAPTAIN SMITH:—I will answer the question by saying that no brakes have been built or installed, to my knowledge, on any vessel. They have simply been designed.

THE CHAIRMAN:—Is there any further discussion on this paper? Doubtless Mr. Hyde will be willing to bring to our notice the results of such further work as may be done in this connection. I trust it will be ready for our next meeting. I am sure you will allow the Chair to extend on your behalf a vote of thanks to Captain Smith for giving us this most interesting paper, and also to authorize the Chair to extend a vote of thanks to Mr. Etter for the paper read by Professor Owen—both valuable contributions to the literature of their respective subjects.

The next paper to be presented is No. 12, "The Maintenance of the Fleet," by Capt. A. P. Niblack, U. S. N., Vice-President.

CAPTAIN NIBLACK:—Under the Navy regulations I was required to submit this paper to the Department to be censored, and one of the conditions under which it is permitted to be read here is that it shall be read verbatim as written, and not interspersed with any remarks. The Society wished me to make an abstract of the paper, to be read here, and thus save you the infliction of the whole paper. I have made the abstracts as requested, but under the conditions just set forth it is necessary that I shall read the whole thing. Therefore, I will read it without alteration of any kind.

THE MAINTENANCE OF THE FLEET.

By Captain A. P. Niblack, U. S. N., Vice-President.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

The first line of the national defense is diplomacy, which, for safety and to avoid misunderstandings, should be in the hands of skilled if not specially trained men. Due to our geographical position, our second line is the navy, which must ever be prepared to act on the offensive, as its chief value lies in mobility and initiative. The third line is the sea coast and other fixed defensive, with a mobile land force to protect the land approaches. From its immobility this third line is essentially defensive. The fourth line is the regular army, which, like the navy, is essentially offensive. The fifth line is the trained reserve, and that we have not. As patriotic and as self-sacrificing as are the individuals who compose the militia, no thinking person, with knowledge of the facts, can count the militia as a trained reserve. For all that it is, we should, however, be deeply thankful. The sixth line is the reserve of equipment—guns, ammunition, clothing, food and fuel—together with the manufacturing establishments to turn out whatever additional is needed, from a button to a battleship. Untrained men, as a war asset, are like ore in the mine, cotton in the bale—simply a valuable raw material. The dear old lady who is represented as singing "I did not raise my boy to be a soldier" is quite right, and she was wise not to undertake it. It takes several years of special training to make a soldier, and it is the duty of the general government, and not even of the various states, to undertake this. She had her work cut out for her getting him through the mumps and measles.

We are prone in this country to regard ourselves as a rich nation. My experience with rich people has been such that I have come to regard mere riches as a severe test of character. Money is certainly not a war asset until it is actually invested in the creation of war material and trained personnel. It is, however, a good thing to use in paying war indemnities, and in that respect we have an attractive bank account. Money not spent in preparedness for war, if no war comes, is not necessarily money saved, for, unhappily, the ideas which spring up like weeds around the noble aspirations of universal peace always tends to sap, strangle and kill the national stamina and deteriorate the national character, whereas the recognition that every citizen owes spontaneously his services to the country in time of war (and hence in time of peace in preparation for war) is an asset independent of national wealth and infinitely more valuable. Except China (and it is almost too late for her to lock the stable door), Great Britain and the United States are the two remaining countries in all the world which cling to the voluntary system of enlistment, because, setting the individual above the state, the individual has been

clever enough to avoid the discomfort, the loss of time, and the interference with his pleasure and business which universal military service demands. As Rudyard Kipling recently said, we expect to raise armies "by the same methods we raise money at a charity bazaar. We profess to believe that in the hour of danger there will always be enough men ready, of their own free will, to defend the country." The voluntary system, however comfortable to the millions, is enormously expensive, unfair, clumsy, unreliable, and generally unsatisfactory. Drafting by lot in times of stress is only a palliative, as shown by the disgraceful draft riots during the Civil War. In countries in which there is conscription there are at least no strikes in government munitions factories and shipyards, and no real agitation for woman suffrage, for the right to vote implies the obligation to bear arms or to manufacture them. One must either fish or cut bait.

However, we all get, in the end, what we deserve, and, when the final reckoning is paid in the war now going on in the world, we may even be able to estimate accurately the relative cost of being, say 100 per cent ready for war as compared with 30 per cent; and we may even find ourselves, somehow, helping to pay the piper. Whatever legitimate differences of opinion, therefore, we may have as to our national policies as a world power, it would seem to be best, instead of discussing the subject of the maintenance of the fleet on the high plane of patriotic or civic duty, to apply the acid test of business, or what pays best in the end.

In the first place, geography has placed a large ocean on either side of us, between us and our powerful neighbors. Looking across the Atlantic, we have always accepted a defensive rôle, and talked, and thought, and built to repel an enemy if he should come. This habit of thought, of waiting for something, of holding back, of expecting things to come to us, has almost destroyed our initiative, has kept back our foreign trade, and almost driven our flag from the ocean. We have reasoned that our fleet would give us time to bring up our supposed reserves and enable us to raise an army of volunteers. Facing this comfortable solution, we have turned our back upon the Pacific.

Geography, acquisitiveness or destiny has presented us in the Pacific with Alaska, the Hawaiian Islands, Tutuila (Samoa), Midway Island, and Guam, as stepping stones across the Pacific, and, by their possession, imposed upon us the same policy as if they were actually in the hands of an enemy or rival, because they exist and cannot be sunk; and if we fail to make the right use of them geography will turn them against us, just as it turned them away from others and to us. The Pacific permits to us no defensive policy such as we have softened ourselves to in the Atlantic. Our coast line extends to Guam, even if we should scuttle in the Philippines. We can wiggle, and squirm, and make a wry face over paying the bill, but we can never evade ultimately the cost of adequately fortifying a naval base in the island of Guam, and in a lesser degree in the island of Tutuila, in the Archipelago of Alaska, and on Midway Island, just as we have already begun the good work in the Hawaiian Islands and at Balboa at the Pacific end of the Panama Canal, the reason being, if there were no other, to prevent their being

used against us as commercial supply stations or naval bases by an enterprising rival or enemy. Besides, it will pay us to do so.

Suppose that on January 1, 1916, there should be assembled off Panama, in the Pacific, a fleet to make a leisurely voyage to Manila and return by way of Honolulu, Midway, and Guam. Let us assume that this fleet consists of 30 battleships, 20 of our largest cruisers (now mostly out of date because deficient in speed), 40 destroyers, 20 colliers, 3 supply ships, and the fleet repair ship Vestal. In order to state the problem of supplying this fleet in its simplest form, the speed is 10 knots, no bad weather is encountered, there are no delays from break-downs, and the time to overhaul machinery, etc., is placed at an absurdly low figure. As the stretch from Panama to Honolulu is 4,685 miles and would necessitate towing some of the ships of lesser coal endurance, and, as touching at Magdalena Bay would only be 125 more than the direct route, this stop is made. Stopping at San Diego, Cal., instead, would have made a difference of 436 miles.

We have at Balboa a fine refueling plant and an embryo naval station, and the fleet is supposed to sail from there full of coal and fuel oil. The assumption is a very liberal one that 18 tons of coal and 3½ tons of oil per mile will cover the fuel consumption of the battleships, cruisers, and destroyers at sea at a speed of only 10 knots, and that 1,000 tons of coal and 160 tons of oil will cover their daily consumption in port. According to *London Engineering* the average collier or freighter will burn 1/6 of a ton of coal per mile (or ⅛ of a ton of oil) and will burn about 12 tons of coal (10 tons of oil) in port per day. Our battleships carry nearly forty days' fresh provisions, and five months' dry provisions, and the three refrigerator supply ships Culgoa, Glacier and Celtic may be emptied on reaching Guam, proceed to Sydney, Australia (3,000 miles), to fill up, and return to Guam to meet the fleet on its return voyage.

The following is the calculated coal consumption for the outward voyage:—

	Sea miles.	*Coal, tons.*	*Oil, tons.*
Panama to Magdalena Bay....	2,265	49,000	8,500
In port 5 days	.....	5,000	800
Magdalena to Honolulu	2,543	55,000	9,500
In port 5 days	.....	5,000	800
Honolulu to Guam via Midway.	3,450	74,700	13,000
In port 10 days	.....	10,000	1,600
Guam to Manila	1,542	33,500	5,800
In port 10 days	.....	10,000	1,600
Total	10,000	232,200	41,600

Taking from the "Naval Pocket Book" the bunker capacities of all the ships enumerated as comprising this fleet, adding to it the carrying capacities of coal and

oil of the twenty colliers, and comparing the sum with the consumptions of fuel in the foregoing table, we have:—

	Coal, tons.	*Oil, tons.*
In bunkers	129,000	16,900
As cargo	120,000	38,100
Total	249,000	45,000
Consumed as per table	232,200	41,600
Margin	6,800	3,400

It should be stated that the two new oil carriers Kanawha and Maumee, now ready for service, are included in the list of colliers. These two help to swell the figures for oil by 18,244 tons. The margin remaining as above is uncomfortably small and we are at once confronted with the problem of 240,000 tons of coal and 40,000 tons of oil required to get the ships back to Balboa. The bunker coal for the colliers can be gotten from Singapore or Australia, but only "Welsh" or "Pocahontas" class of coal serves for naval use. The problem, as elementary as it may seem, is extremely complicated even in time of peace. What it would be in war is another matter, but it illustrates the profoundly gratifying fact that we have wisely given our ships a large steaming radius, and, more wisely still, gone in for government-owned colliers and supply ships, while every other navy in the world has to rely on chartering. With adequate supplies of coal and oil at Honolulu, Midway and Guam, we may attain the desired mobility of the fleet even in war, provided we adequately fortify Guam and Midway. The cost would not exceed that of one battleship.

In time of war the high speeds required in scouting and protecting would increase enormously the demand for fuel, and the 10 knots speed for the fleet shows how narrow is the margin as it gives the very minimum, easily increased by leaps and bounds under stress of weather or war operations. It is estimated that probably 200,000 tons of coal a month would be required along this route in time of war. Two things stand out clearly in this problem, viz., the necessity for adopting the system of towing and coaling at sea so ably and so often advocated in the meetings of this Society, and the need of replacing our old colliers, supply ships and cruisers with newer, larger and faster ones. These colliers, repair and supply ships, fitted with 5-inch and 6-inch guns and officered and manned by regular officers and men, should be able to give a good account of themselves in time of danger and would not need the sheltering and shepherding that must be given to a heterogeneous lot of chartered and irresponsible craft, none too reliable under the most favorable circumstances. This leads up to the question of either purchasing additional colliers and supply ships, or building them, as we cannot rely on chartering because we will need all the available merchant ships for other purposes, viz., our expanding foreign trade, and maintaining what we have. A purchased ship

will require at least two months to overhaul and adapt her to government requirements. During the "War with Spain" we purchased colliers having a gross tonnage of 42,500 tons at a cost of $76 per gross ton. Economy and serviceability point to the entire desirability of building ships for the special service required. We have worked out and know every detail of what we want as colliers, oilers, refrigerator, repair, transport, water tank, ammunition, and hospital ships, torpedo-boat destroyers and submarine tenders, mine layers, mine sweepers, merchant scouts, aeroplane transports, tugs, coal lighters, and buoy tenders.

In supplies are included reserve ammunition, medical stores, fresh and dry provisions, clothing, equipment, fresh water, "canteen" stores, both afloat in supply ships and at the naval bases. Fuel means the ability to deliver the blow without delay. Delay means the loss of the initiative. Operations can only be based on available means, and, in modern war, you cannot plan and then assemble stores to execute the plan. After war is declared it becomes a question of supplies and weapons at the front, or else falling back on the defensive and trying to gather from every source the supplies needed even for the defensive. With fortified island bases each would become a stepping stone to the next, and a center from which to sally forth, attack and harass, and to which to return for supplies, rest and overhaul. Our real coast line would become, as it were, more remote from our enemy as these obstacles in his path hindered his free movements, and, on the other hand, these island bases would have the effect of extending our coast line out into the ocean for our own forces. As sources of supply they are as valuable to the enemy as to us, unless we fortify them adequately and defend them with submarines, torpedo boats and mine devices.

All this sounds like the stock language of the rampant militarist looking for and bringing on trouble, but is simply the cold business of insurance against and avoidance of trouble through prevision and provision. There is, moreover, no reason in forbidding business in foreign relations, or diplomacy in making for markets and trade opportunities. Tutuila, Midway and the Aleutian Islands come into the question of island bases as auxiliary centers of supply and security, or as centers of scouting and offensive, not to mention commercial operations. Over and above all lies Guam in its position of unique, commanding and supreme importance, the "Key of the Pacific." On what we do there depends our future on that ocean, and as a peaceful, law-abiding and properly respected member of the community of nations. If we rise to the occasion, no one can take the Philippines if we should let go, or drive us out until we choose to go in our own time and in our own way. Geography is knocking loudly at our door.

No one can trouble the fishing industries and rich coal fields in our storehouse of the future in Alaska if there is a fortified base in the Aleutian Archipelago. Tutuila, 5,700 miles from Panama, 2,276 from Honolulu, 3,159 from Guam, and 4,500 from Manila, is only 1,565 miles from Auckland and 2,377 from Sydney, with their supplies of fresh provisions and coal. The Panama Canal has made its beautiful landlocked harbor a priceless heritage in our manifest destiny

in the Pacific. Midway, at present an indispensable cable relay station, 1,150 miles beyond Honolulu, near the route to Guam, has a harbor with a bar good for 17 feet draught now, and which the cost of one cruiser would convert into an auxiliary fortified and equipped island base. Many visits, in connection with constructive work and planning, have made its every feature familiar and of deep interest to me, and I look forward to the time when wise foresight will guard this vulnerable outpost in the ocean on which our future lies.

All this talk of fortification and equipment means less than the cost of two battleships, and without which the battleships are restricted to operations from bases improvised after war is declared. The money spent annually in soda water, chewing gum and candy, if spent on reasonable military necessities would put us in the hated class of the "prepared." The cost for one day of the war now going on in the world would secure the Pacific coast from invasion for all time. Everyone knows this, but like the Jews of old we consider ourselves the chosen people, and the voices of those who could pilot the job are as those crying in the wilderness of local politics.

The question of maintenance of the fleets is separate from that of organization, training and operation. But as to the supply of trained officers and men, as affecting the maintenance of the fleet, so many more than the present number could be utilized to advantage, and so much remains to be done, that it is best not to discuss it. As short-handed as we are the training goes on incessantly, as it should, and the spirit of competition keeps anyone from getting a swelled head as to being the latest prodigy in any line of endeavor. Many prizes are given and adherence to rules, in competitions, like obedience to orders, is ingrained. The science of getting the most out of each ton of coal and gallon of oil, under the spur of competition, has, as an example, enabled two of our fifirst dreadnoughts to make a knot more speed in full power than their contract, and cut the coal consumption in port in half, as compared with their first year in commission. Every battleship in the fleet can today make her contract speed and most of them can exceed it.

Suppose we had a Supreme Council of War, whose composition commanded the confidence of everyone. The result would be that people would say, "The Council says this must be done," and everyone would accept it as a national necessity. The Council might say, "We must have an interior water-way from Cape Cod Bay to the Gulf of Mexico for urgent strategic reasons," or "In every other country in the world the coast defenses are under the navy, in order to insure co-ordination. The Coast Artillery Corps must be transferred to the jurisdiction of the navy, just as the Marine Corps now is." In fact it is just the knowledge that such recommendations would be made that keeps us from getting the Council of National Defense. As a friend of mine used to say, "When pain or fear wrench hard enough on the purse strings, the doctor gets called in," and like the sick man we can only hope that it will not prove too late, if necessity ever forces the calling together of such a council.

Of the seventeen paragraphs of the Constitution of the United States which

define the powers of Congress, nine of them deal with providing, organizing and maintaining "the common defense" in such uncompromising language as seems to voice the suspicion of its framers as to the probable location of the lamb on that great day when the lion and the lamb shall lie down together, and even to suggest that the happy after-dinner speech of the lion is not a safe basis for framing a policy of national defense. The founders of this nation even seemed to suspect that a federation of states would not, as a form of government, sufficiently maintain preparedness, and therefore took great pains to fix the responsibility on the legislative branch of the general government. If it is true that the people really rule this country—and they are constantly told they do—and yet shrink from facing issues which involve any sacrifice of their time, pleasure or comfort, then the standard of citizenship is perilously low, and government by the people is seriously on trial.

DISCUSSION.

THE CHAIRMAN:—The other day the Chair had the privilege of being greeted as an "old landmark" of the Society and as such an "old landmark" he will call to your attention something which happened about twenty years ago at one of the early meetings of this Society. The then Lieutenant Niblack read what was supposed to be a very quiet and innocuous paper, which dealt with a subject which was quite a live issue at that time, namely, the coaling of ships. Before we could properly muzzle the discussion, it consumed about two-thirds of our available time. The subject then treated was a mere bagatelle in importance compared with the one he has brought to our attention this morning. It is refreshing to have someone in the military service who knows what he is talking about, present things of such vital consequence in such terse, effective and convincing form. It is our good fortune that Captain Niblack had to present this paper in its entirety, for to have had it read by abstract would have doubtless deprived us of some of its best portions.

The matters touched upon by him affect the country at large, even more than they affect those who happen to be in the military or naval service. If, by the presentation of facts of this kind, we can arouse our colleagues in civil life to a realization of national conditions —and we surely do not help ourselves by refusing to see the things that are before our eyes—such efforts will not have been in vain.

I have recently returned from a visit to the west coast of this country. It is gratifying to find that nearly everywhere out there these questions are taking a vital hold upon the people; that the great question of unselfish devotion to country and preparation for national defense—not preparedness for national aggression—was getting to be a very live issue; that to take time by the forelock and prepare themselves to protect, if necessary, their national welfare was all-important. But no one desires preparation for aggression, only preparation for the prevention of possible invasions and resultant destruction of all that is held most dear.

I merely make these remarks in introducing to your attention Captain Niblack's paper. It deals with vital issues, and it is well worthy of our careful and painstaking consideration. I trust that it will be fully and freely discussed, but, of course, in a most conservative and helpful way.

Mr. E. H. Rigg, *Member:*—There is nothing I can say except what is congratulatory to the Society on the fact that we have such a paper as this before us at this time.

Captain Niblack's paper deals more particularly with preparedness from a naval point of view, and of course that is the point of view from which we are most interested in the subject.

I think it is perhaps pertinent to inquire—although if I am getting too far into the sphere of politics I hope the Chair will stop me—what would be Great Britain's situation today if her navy had not been ready? Back of that navy she has multiplied her military efficiency by anything you like, from 20 to 30. Her army consisted of something like a quarter of a million soldiers, and that army has been raised to at least fifteen times that number. If it had not been for an effective navy, I do not think it need be said she would never have had a chance to get that army in shape. That is one argument for preparedness, and is a very important one, from our point of view also.

I would like to raise a question which has been agitating us all very much of late, especially in New York State and in the state in which I live. Captain Niblack in his paper, near the top of page 108, says: "In countries in which there is conscription there are at least no strikes in government munitions factories and shipyards, and no real agitation for woman suffrage, for the right to vote implies the obligation to bear arms or to manufacture them. One must either fish or cut bait."

According to the pictures and accounts that have recently come to hand, the women in the belligerent countries are both fishing and cutting bait. From Servia we read of women serving in the trenches in considerable numbers, and in Britain and other countries they are working in men's places in countless fields of activity and in munition factories in great numbers.

The other great work that women do in war, namely, nursing the wounded and sick, and thus directly assisting in the return of the slightly wounded to the firing line, apart from their care of those who will never be able to go back, also must be remembered. In a war of the magnitude of the present one, the whole population, male and female, is involved, and the old idea that women take no active part in war is exploded; they assist in maintaining the efficiency of the fighting man and his equipment to an extent they have never done before.

The Chairman:—Is there any further discussion? If not, we will ask Captain Niblack to close.

Captain Niblack:—I merely wish to say this paper is in line with the attitude of thinking people who stand for adequate preparedness. It calls attention to a condition of affairs which I have become familiar with during twelve years' sea service in the Pacific Ocean, through cruising in all parts of it. It is a frank statement aimed at no other country, but intended merely to preserve our interests in the Pacific, which are more or less threatened. It is dangerous to leave property lying around loose in the present state of the political unequilibrium of the world.

THE CHAIRMAN:—We now pass to the next paper, No. 10, entitled, "Period of Vibration of Steam Vessels," by Mr. William Gatewood, Member. We will be glad to have Mr. Gatewood present his paper in person.

MR. GATEWOOD:—I want to apologize to the Society for presenting a paper containing so many mathematical formulæ, and for two reasons: First, there are few who really enjoy mathematics; and second, the mathematics in this paper is of the vintage of over thirty years ago, and the bottle has been left uncorked and possibly it is a little bit sour.

There have been read before the Society several papers on the subject of balancing engines, but, so far as I am aware, nothing has been read before the Society relative to the effect of the unbalanced forces of the engine on the structure of the vessel. So I have taken this opportunity of presenting a few thoughts on the subject. Almost everyone has experienced the discomforts of the vibrations of steam vessels, and some of you, perhaps, have experienced the discomforts of the vibrations of the Ford motor car. I am at liberty to mention the Ford car, because it has a close relation to some classes of war vessels.

When the turbine installation was first put into vessels, it was considered that the discomforts of vibration would be eliminated. It was found, however, that while they were greatly reduced, there were still some vibrations left. It is possible that, when the electric drive is perfected, the vibration of steam vessels will be further reduced.

As is well known, in all calculations relative to the strength of vessels, the vessel is considered as a beam and the stresses are determined by the beam formulæ. So it seemed to me only natural that the period of vibration of a vessel could be worked out by considering the period of vibration as that of a beam. I have therefore presented to the Society some statements relative to the laws governing the period of vibrations of beams, and the application of these laws to the case of a floating vessel.

Mr. Gatewood then presented his paper.

PERIOD OF VIBRATION OF STEAM VESSELS.

By William Gatewood, Esq., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

The author was led to investigate this subject by the vibrations which occurred in service on an oil tanker built by the shipyard with which he is connected. This tanker is 460 feet long and is fitted with a quadruple expansion engine installed in the stern, designed to indicate about 2,800 horse-power at 78 revolutions per minute. When running in ballast condition, no vibration was experienced. When loaded, however, longitudinal vibrations in a vertical plane were experienced with the engines turning at revolutions between 72 and 76. These vibrations were of the two-nodal character, and their period corresponded with the revolutions of the main engines. After several trips, the pitch of the propeller was increased so that the revolutions in service might be less than 72, and under the altered conditions no vibration was experienced.

In order to investigate the matter more thoroughly, however, observations were taken on the vessel after the pitch of the propeller had been increased. The methods of taking observations were somewhat primitive and consisted of a device for measuring variations in the shape of the vessel in a vertical plane and another device for measuring the change in length of the deck plating.

A vertical batten marked off in inches was set up at mid length of the vessel, in line with the inner edge of the shelter-deck stringer plate. A horizontal batten was located at the height of the rail abreast the after end of the engine casing. An observing station was established at the outboard end of the breakwater near the bow. The distance from the observing station to the vertical batten was 192 feet 8 inches, and from the vertical batten to the horizontal batten was 189 feet 2 inches, a total distance of 381 feet 10 inches. This was the longest fore-and-aft sight obtainable. The method of observing was to sit on the breakwater with head against the rail and with binoculars to watch the motion of the horizontal batten past the divisions on the vertical batten.

Five stations were located for observing the stretching and compression of the shelter-deck stringer plate. No. 1 station extended from the breakwater for 90 feet aft on the line of the inner edge of the shelter-deck stringer plate. No. 2 station overlapped No. 1 station, and extended 90 feet from just forward of the bridge-house to nearly amidships. No. 3 station overlapped No. 2 station and extended 90 feet over the mid length of the vessel. No. 4 station overlapped No. 3 and extended 90 feet from forward of the mainmast to aft of the after cofferdam. No. 5 station overlapped No. 4, and extended 90 feet from the after coffer-

dam to the after end of engine casing. The method of observing was to secure one end of a steel tape to the heel of a rail stanchion and to hold the other end in the hand with constant tension, watching the motion of the 90-foot mark past a scratch on the deck plating.

The observations took place in the Gulf of Mexico in July, 1914, with the vessel loaded with about 11,000 tons, deadweight. The revolutions of the main engine were increased from 68 to 74, when a slight vibration became noticeable. It could not be measured by the battens, but at No. 3 station the motion amounted to about $\frac{1}{32}$ inch in 90 feet. When the revolutions were increased to 76, the vibrations were quite appreciable. The motion on the batten amounted to about ½ inch total. It was difficult to determine this with exactness, as it varied slightly, but it never appeared to exceed ¾ inch, and ½ inch seems near the true reading. The motion in 90 feet as determined by the tape line was $\frac{1}{64}$ inch at No. 1, $\frac{1}{32}$ inch at No. 2, $\frac{1}{16}$ inch at No. 3, $\frac{3}{64}$ inch at No. 4, and $\frac{1}{64}$ inch at No. 5. The number of vibrations corresponded with the revolutions of the engine and could be easily counted by the motion of the tape. The type of vibration was of the two-nodal character, in which the bow and stern drop as the midship portion of the vessel rises, and rise as the midship portion drops. The nodes seemed to lie near the after end of the bridge deck-house and at the after cofferdam, but it was difficult to decide where the nodes were.

The variation in stress in the shelter-deck stringer corresponding to $\frac{1}{16}$ inch variation in length in 90 feet amounts to about 1,700 pounds per square inch. The deck was already in compression, and the additional compressive stress therefore amounted to about 850 pounds per square inch.

During the tests the sea was smooth. When the engines were slowed down, the vibrations ceased. When the revolutions were raised to 76 again, so that indicator cards might be taken, the vibrations reappeared, and of the same intensity as before.

Here seemed to be a case of synchronism between the revolutions of the main engine and the period of vibration of the hull structure occurring in the working range of revolutions of the engine on a vessel of low speed. The literature on the subject to which the author had access did not seem to be complete as regards the period of vibration of the hull structure, although approximate formulæ were given by Herr Schlick in a paper read by him in 1894 before the Institution of Naval Architects in England.

From the considerations set forth in the Appendix, it would appear that the general formula for small isochronous vibrations is

$$T=\frac{2\pi}{\sqrt{g}}\sqrt{\frac{k^2}{\delta}} \qquad (1)$$

in which T is the time in seconds for a double vibration; g is the acceleration of gravity; k^2 is the square of the radius of gyration in feet, in the value of the

kinetic energy; δ is the movement of the weight in feet, in the expression for the work done.

From formula (1) the expression for the number of vibrations per minute is obtained:—

$$\text{V. P. M.} = \frac{60}{T} = \frac{54.15}{\sqrt{\frac{k^2}{\delta}}} \qquad (2)$$

The purpose of this investigation is to determine the above-mentioned formulæ, and how the values of k^2 and of δ, which should be used in them, can be obtained when the period of vibration of a vessel is in question. In order to prepare the way for this latter problem, the simpler cases are discussed at some length in the Appendix.

A vessel is a beam of varying moment of inertia of section "I," irregularly loaded, and supported by fluid pressure. In order to simplify the calculations, the moment of inertia "I" may be considered constant, although in some types of vessels a considerable error would be introduced by this assumption. The curve of weights is plotted from the data available, and the curve of buoyancy in still water is obtained from the lines. The difference between the ordinates of these two curves gives the curve of loads. The curve of "loads" is integrated graphically, and the resulting curve is the "shear" curve. By integrating the "shear" curve, we obtain the curve of "bending moments in still water." The process to this point is that commonly in use in ship calculations. Plate 56 shows the results for the oil tanker previously mentioned.

By integration of the moment curve, we obtain curve of "angle of deflection" and by integration of this curve we obtain curve of actual "deflection." The integration of the moment curve should preferably start at amidships and proceed both ways. Plate 57 shows the resulting deflection curve rectified to show same amount of deflection at stem and propeller post. If account had been taken of varying moment of inertia of section, this curve would be slightly modified, but probably inappreciably, as "I" hardly changes for three-quarter length amidships in the vessel selected.

The question next to be settled is the position to be assumed for the points of support of the vessel considered as a beam. After giving the matter some thought, it was concluded that this might be determined by obtaining the mean immersion by taking the load-water plane of the vessel and determining the volume of the buoyancy included between the "deflection" curve and the horizontal at the lowest point of this curve. Dividing this result by the area of the load-water plane, we obtain the mean immersion which will give the same volume. We plot a line across the rectified "deflection" curve at this height above the lowest point amidships. The crossings of this line and the deflection curve will represent the points of support, as, if the vessel were to straighten out, this is the height at which it would float, the buoyancy lost by the rising of the midship part being balanced

by the buoyancy gained at the ends, considering that there would be no appreciable change in trim.

The total work would be that done in deflecting the vessel considered as a beam, or, from (39), (46) and (47), in the Appendix,

$$U = W\delta = \tfrac{1}{2}\int_0^L Mdi + \tfrac{1}{2}\int_0^L (w-b)(y_s-y)\,dx \tag{3}$$

and, since the two parts are equal,

$$\delta = \int_0^L \frac{M^2 dx}{WEI} \tag{4}$$

in which W represents the total weight of the vessel, or the displacement; $w - b$ represents the varying weight per foot run of the vessel as read from the "load" curve; and $y - y$ is the deflection measured from the mean immersion line.

To obtain k^2, we use the formula—

$$k^2 = \int_0^L \frac{w(y_s-y)^2 dx}{W} \tag{5}$$

in which w is the varying weight per foot run of the vessel as read from the weight curve (not the "load" curve), and W is the total weight of the vessel.

The value of $\frac{k^2}{\delta}$ obtained for the vessel with data on Plates 56 and 57 is—

$$\frac{k^2}{\delta} = \frac{.004147}{.01278} \text{ feet} = .3244 \text{ feet} \tag{6}$$

whence

$$\text{V. P. M.} = \frac{54.15}{\sqrt{.3244}} = 95.08 \tag{7}$$

It will be noted that the period for the vessel shown on Plates 56 and 57, as calculated, is about 95 vibrations per minute. This is the same vessel, however, on which the vibrations were measured and found to be about 76 per minute. The discrepancy indicates an error in the assumptions. At first it was thought that the rigidity of a hollow riveted structure such as a vessel would be less than if it were a homogeneous steel structure. This is probably true to a certain extent, and the value of E to be used in the formula should be taken at somewhat less than its accepted value, perhaps. Also, the value of I varies, depending on whether it is taken in way of a bulkhead or between bulkheads. It is recognized also that there is a deflection of a beam due to shear action as well as to bending action.

In addition to the preceding causes affecting the deflection, a correction would be necessary on account of the fact that the value of the kinetic energy was obtained by considering the weight of the vessel as the mass given motion in the vibration, and the fluid effects were neglected. There is no doubt that the vertical

motion of any part of the vessel is accompanied by a motion of the adjacent water, and that the mass given motion is really greater than was assumed. But none of these corrections seem sufficient to account for the discrepancy.

The vessel was considered as a beam with loads concentrated along the neutral axis. Actually, the depth of the vessel is about one-twelfth of the length, and the loads are distributed throughout the depth of the vessel. Some of the weight, indeed, is at quite a distance from the neutral axis. If the vessel were a beam supported at the ends, this would not introduce a very serious error into the calculations. But when the points of support are near the quarter-length of the vessel, the relative effect is greatly increased, as so much of the weight has fore-and-aft motion during the vibration, with no appreciable vertical movement. It is considered that the effect of taking into account in the calculations the vertical distribution of the weights on the vessel will be to increase the value of $\frac{k^2}{\delta}$ about 56 per cent, and to decrease the number of vibrations per minute from 95 to about 76, the observed value.

If the vessel in question is typical, the number of vibrations per minute as calculated, without allowing for the vertical distribution of the weights, would need to be reduced by about 20 per cent to obtain the actual figure.

When a beam vibrates, the reactions at the supports are affected. The probable effect in the case of a vessel with deflection curve as shown on Plate 57 may be obtained by considering that the reactions are least when the beam has least flexure, and the reactions are greatest when the beam has maximum flexure, and in each case correspond to the steady condition which would produce the flexure. By analogy from the "Rod in Tension," considered in the Appendix, the weight (in this case the vessel as a whole) will be at its top position when the unbalanced force tending to lower the weight is greatest, and at its bottom position when the force tending to raise the weight is greatest. In the case of the vessel, the draft will be least when the flexure is greatest, and the draft will be greatest when the flexure is least.

The amount of the dipping motion as determined in the Appendix, considering the amplitude of the vibration as one-tenth of the deflection in each direction, amounts to .00678 foot. Plate 58 shows this forced "dipping" motion combined with an assumed amplitude of vibration of one-tenth of the deflection, and from this it appears that the effect is to cause the nodes to approach each other, to reduce the vertical motion amidships, and to increase the motion at the ends.

The nodal points as observed on the vessel are marked on Plate 58, but no special means were used to locate them accurately.

Attention is invited to the fact that in shoal water, on the vessel observed, vibration seems to start at about six revolutions per minute less than it starts in deep water. No explanation is apparent.

It will be noted that $\frac{k^2}{\delta}$ for any vessel considered as a beam is a function of

the weight or displacement multiplied by the cube of the length and divided by the moment of inertia of the midship section, or

$$\frac{k^2}{\delta} = C\left(\frac{\triangle \times L^3}{I}\right) \tag{8}$$

The coefficient, however, is seen to vary as the loading changes, since the bending moment curve alters with the loading, and the deflection curve also. If the displacement be expressed in long tons; the length to propeller post, in feet; and I, in feet:—

For the vessel Plates 56 and 57,

$$\text{V.P.M.} = 1{,}619{,}000\sqrt{\frac{I}{\triangle \times L^3}} = 76, \text{ as observed.} \tag{9}$$

APPENDIX.

SIMPLE PENDULUM.

FIGS. 1 AND 2, PLATE 59.

Let a weight W be suspended from a point C by a weightless rod of length l (Fig. 1, Plate 59).

If the weight be raised to A and released, it will swing about the point C, passing through O, vertically below C, and continuing to a point on the opposite side practically as high as A, when its motion will be reversed, and it will swing back toward A again, etc.

The work done in swinging from A to O will be Wy_1, where y_1 is the height of A above O. Neglecting friction, this work will be the amount of kinetic energy of the weight as it passes O with velocity V_0, or $Wy_1 = W\frac{V_0^2}{2g}$. Also, the work done at the time of passing B would be $W(y_1 - y)$, and the kinetic energy $W\frac{V^2}{2g}$, the velocity at the point B being V. Equating, we have—

$$W(y_1 - y) = W\frac{V^2}{2g}$$

and

$$V = \sqrt{2g(y_1 - y)} \tag{10}$$

If the chord of the arc OA have length S_1, and of arc OB, S, then by construction—

$$y_1 = \frac{S_1^2}{2l}, \text{ and } y = \frac{S^2}{2l} \tag{11}$$

Substituting values of y_1 and y in equation (10), we have—

$$V = \sqrt{\frac{g}{l}} \times \sqrt{S_1^2 - S^2} \tag{12}$$

$$V_0 = S_1\sqrt{\frac{g}{l}} \tag{13}$$

$$V = \frac{V_0}{S_1}\sqrt{S_1^2 - S^2} \tag{14}$$

To determine the period of swing, lay off a half circle with radius $= S_1$ (Fig. 2, Plate 59), and consider a point on the circumference to move with uniform velocity V_0. When the point is at D, the component of the velocity parallel to OA, V, will be

$$V = V_0\frac{BD}{OD}$$

If OB is called S, then

$$BD=\sqrt{\overline{OD}^2-\overline{OB}^2}=\sqrt{S_1^2-S^2}$$

and

$$V=\frac{V_0}{S_1}\sqrt{S_1^2-S^2} \tag{15}$$

It will be seen, therefore, that the component parallel to a diameter, of the velocity of a point which travels with uniform velocity in a circular path, bears the same relation to the velocity of the point that the velocity of the simple pendulum at any point of its swing bears to the maximum velocity of the pendulum. If, then, the pendulum swings through such a small arc that the chord and arc may be considered identical, the time taken to swing through arc S_1 will be the same as it takes the point in Fig. 2 to move through a quadrant of radius S_1, or

$$t=\frac{\frac{\pi}{2}\times S_1}{V_0}=\frac{\frac{\pi}{2}\times S_1}{S_1\sqrt{\frac{g}{l}}}=\frac{\pi}{2}\sqrt{\frac{l}{g}} \tag{16}$$

The time required for a double swing, or from A back to A again will be

$$T=4t=2\pi\sqrt{\frac{l}{g}}=\frac{2\pi}{\sqrt{g}}\sqrt{l} \tag{17}$$

In this case, where the weight is considered concentrated at a point, the expression $\sqrt{\frac{k^2}{\delta}}$ of equation (1) is replaced by $\sqrt{l}$, the length of the simple pendulum.

COMPOUND PENDULUM.

FIG. 3, PLATE 59.

If the weight be not concentrated at a point as in the case of a simple pendulum, but the pendulum consists of a bar of length L and unit weight of w pounds (Fig. 3, Plate 59), the work done in swinging from A to O will be wLy_1, where y_1 is the height of the center of gravity of the bar above its lowest point. The kinetic energy of the bar as it passes the vertical, will be—

$$\int_0^L \frac{wdL\times L^2\alpha_0^2}{2g}=wL\times\frac{L^2}{3}\times\frac{\alpha_0^2}{2g}$$

where α is the angular velocity.

Equating work and kinetic energy, we have—

$$wLy_1=wL\times\frac{L^2}{3}\times\frac{\alpha_0^2}{2g}$$

$$\alpha_0^2=\frac{2g.y_1}{\frac{L^2}{3}}=2g\frac{y_1}{k^2}$$

if we call $\frac{L^2}{3}$ which is the square of the radius of gyration, $= k^2$.

Similarly for any intermediate position B,

$$\alpha^2 = \frac{2g(y_1 - y)}{k^2} \tag{18}$$

If the chord DE have the length S_1, and the chord HE the length S, then $y_1 = \frac{S_1^2}{2\delta}$, and $y = \frac{S^2}{2\delta}$ where δ is the radius to the center of gravity $= \frac{1}{2}L$. Substituting the values of y_1 and y in (18), we have

$$\alpha = \sqrt{\frac{g}{k^2\delta}}\sqrt{S_1^2 - S} \tag{19}$$

$$\alpha_0 = s_1\sqrt{\frac{g}{k^2\delta}} \tag{20}$$

$$\alpha = \frac{\alpha_0}{S_1}\sqrt{S_1^2 - S^2} \tag{21}$$

where S_1 and S are chords with radius δ.

The maximum angular velocity of the simple pendulum from (13) would be—

$$\alpha_0 = \frac{V_0}{l} = \frac{S_1}{l}\sqrt{\frac{g}{l}} = \theta_0\sqrt{\frac{g}{l}} \tag{22}$$

where $S_1 = l\theta_0 =$ arc with radius l.

Similarly from (20), the maximum angular velocity of the compound pendulum would be—

$$\alpha_0 = \delta\theta_0\sqrt{\frac{g}{k^2\delta}} = \theta_0\sqrt{\frac{g}{\frac{k}{\delta}}} \tag{23}$$

From a comparison of equations (22) and (23), it appears that for the compound pendulum $\frac{k}{\delta}$ corresponds to l for the simple pendulum, and the formula for the period of the compound pendulum would be—

$$T = \frac{2\pi}{\sqrt{g}}\sqrt{\frac{k^2}{\delta}} \tag{24}$$

where $\frac{k^2}{\delta}$ replaces l in formula (17).

ROD IN TENSION.

FIGS. 4 AND 5, PLATE 59.

Let a weightless rod of definite length be suspended from a point C, with lower end at D. When a weight W is attached to the end and gradually lowered, the rod will stretch until the end of the rod reaches some point O (Fig. 4, Plate 59). Call the stretch δ.

In Fig. 5, Plate 59, lay out DO equal to the amount of the stretch of the rod from condition with no weight attached to condition with weight W attached and at rest. Let OP, DL represent to scale the weight W. Join D and P. Then, if the weight is raised a distance S_1 to point A, the portion of the weight carried by the rod will be represented by AE. If the weight is now set free, it will fall to some point Z below O, and then will rise to A, if friction is neglected, and continue the vibratory motion about O as a mean position. When the weight is at point B, distant S above O, coming down, the accelerating force F will be represented by MN, the difference between the total weight and the tension of the rod. By construction,

$$\frac{MN}{DL}=\frac{S}{\delta} \text{ or } F=W\frac{S}{\delta} \tag{25}$$

The work done by the weight in falling from A at the time of passing O is WS_1, represented by the area $AOPG$. Of this, the area $AOPE$ represents the work done in extending the rod, and the area PGE represents the work done in accelerating the weight.

The area

$$PGE = \tfrac{1}{2}EG \times GP = \tfrac{1}{2}W\frac{S_1}{\delta}\times S_1 = \tfrac{1}{2}W\frac{S_1^2}{\delta} \tag{26}$$

This will be equal to the kinetic energy of the weight when passing O, with velocity V_0, or

$$W\frac{V_0^2}{2g}=\tfrac{1}{2}W\frac{S_1^2}{\delta} \tag{27}$$

and

$$V_0=S_1\sqrt{\frac{g}{\delta}} \tag{28}$$

Similarly, the work done in accelerating the weight in falling from A to B will be represented by the area $MNGE$, and this will equal the kinetic energy of the weight in passing B with velocity V, or

$$W\frac{V^2}{2g}=\tfrac{1}{2}W\frac{S_1^2}{\delta}-\tfrac{1}{2}W\frac{S^2}{\delta}=\tfrac{1}{2}W\frac{S_1^2-S^2}{\delta} \tag{29}$$

From this we obtain the value of V:—

$$V=\sqrt{\frac{g(S_1^2-S^2}{\delta}} \tag{30}$$

and from (28)

$$V = \frac{V_0}{S_1}\sqrt{S_1^2 - S^2} \tag{31}$$

It will be seen that the character of the motion is exactly the same as in a simple pendulum, and the period can be obtained in the same manner. The time occupied by the weight in moving from A to O, with variable velocity, will be the same as the time taken in traversing a quadrant of radius $AO = S_1$ at the velocity V_0 of the weight when passing O.

$$t = \frac{\frac{\pi}{2}S_1}{V_0} = \frac{\frac{\pi}{2}S_1}{S_1\sqrt{\frac{g}{\delta}}} = \frac{\pi}{2}\sqrt{\frac{\delta}{g}} \tag{32}$$

The conditions after passing O are the reverse of the conditions of the approach, the kinetic energy being converted into work, and the same formulæ hold. The time of a double vibration from A to Z and back to A again will therefore be

$$T = 4t = 2\pi\sqrt{\frac{\delta}{g}} = \frac{2\pi}{\sqrt{g}}\sqrt{\delta} \tag{33}$$

By comparing this with equation (17), it will be noticed that the period is the same as that of a pendulum of short swing having a length equal to δ, the total extension of the rod to position of equilibrium. The period of the rod in tension is not dependent on the amount of the vibration so long as the tension is not entirely relieved, and so long as the extension of the rod is proportional to the force acting on it.

A further consideration of the subject will indicate that when the accelerating force is directly proportional to the distance of a body from neutral position, the period of vibration will vary as the square root of the distance from neutral position to point where accelerating force is equal to the weight of the body. The period is that of a short swing pendulum having a length equal to the above-mentioned distance.

CANTILEVER OF UNIFORM SECTION LOADED AT END.

FIG. 6, PLATE 59.

Let the cantilever be assumed of uniform section and without weight, of length l, and loaded at the free end with weight W. Before the weight is applied, the free end is assumed at A in same level line as the fixed end C. When weight is applied and brought to rest, the free end will be at O, the position of neutral equilibrium, and the deflection will be some length δ. Let x and y be the coordinates of any point B on the cantilever when in neutral equilibrium, and let i be the angle made by a

tangent to the curve at B with the horizontal axis. For relatively small deflection,

$$i = \frac{dy}{dx} \tag{34}$$

and

$$\frac{di}{dx} = \frac{d^2y}{dx^2} = \text{reciprocal of radius of curvature} = \frac{M}{EI} \tag{35}$$

Applying the above formulæ to the cantilever in question, we find that, at any point B

$$M = W(l-x)$$

and

$$\frac{di}{dx} = \frac{d^2y}{dx^2} = \frac{W(l-x)}{EI}$$

By integration,

$$i = \frac{dy}{dx} = \frac{W\left(lx - \frac{x^2}{2}\right)}{EI}$$

And by further integration,

$$y = \frac{W\left(\frac{lx^2}{2} - \frac{x^3}{6}\right)}{EI}$$

By making $x = l$, we find

$$\delta = \frac{Wl^3}{3EI} \tag{36}$$

Since by (36) the deflection varies directly as the load, the accelerating force when the weight is raised and released will vary directly as the distance from the neutral position, and will equal the weight when the weight is raised to the level, a distance $= \delta$. The period of vibration therefore will be given by the formula (33).

$$T = \frac{2\pi}{\sqrt{g}}\sqrt{\delta} \tag{37}$$

CANTILEVER OF UNIFORM SECTION UNIFORMLY LOADED.

FIG. 7, PLATE 59.

Let the weight per unit length be w. The bending moment at any point B will be

$$M = w(l-x)\left(\frac{l-x}{2}\right) = \frac{w(l-x)^2}{2}$$

Applying formula (35), integrating and making $x = l$, we find

$$\text{Deflection of end of cantilever} = \frac{wl^4}{8EI} \tag{38}$$

This deflection is evidently not the deflection of the total weight. The deflection to be used in calculating the work is the deflection of the center of gravity of the total weight, and that is found as follows:—

Let wdx be the weight on length dx at any point B of the cantilever, whose deflection is y. Then $wdx.y$ will be the moment of this weight about the axis X, and $\int_0^l wydx$ will be the total moment about that axis. If this be divided by wl, the total weight, the result will be the deflection of the center of gravity of the load, or

$$\delta = \int_0^l \frac{wydx}{wl} \tag{39}$$

From this we find—

$$\delta = \frac{wl^4}{20EI} \tag{40}$$

In this case, however, where the load is not concentrated, while $wlx\delta$ represents the total work, including both the work done in deflecting the beam to neutral position from position of no load, and also the work done in lowering the weight, it does not represent the kinetic energy of the loaded cantilever, because all parts of the weight have not the same velocity. The velocity of any point is proportional to the deflection at that point. The virtual center of mass would be obtained as in the case of a compound pendulum, by determining the square of the radius of gyration, using the deflection of each point, however, instead of the distance of the point from the pivot. If k^2 be the square of radius of gyration so obtained, the equivalent pendulum will have a length $\frac{k^2}{\delta}$ instead of δ, just as in the case of the compound pendulum.

The period of vibration of the uniformly loaded cantilever will then be—

$$T = \frac{2\pi}{\sqrt{g}}\sqrt{\frac{k^2}{\delta}} \tag{41}$$

where δ is the deflection of the center of gravity of the weight, and k^2 is the square of radius of gyration.

The radius of gyration is obtained by the formula—

$$k^2 = \int_0^l \frac{wy^2dx}{wl} \tag{42}$$

Solving, we find

$$k^2 = \frac{13w^2l^8}{3240E^2I^2} \tag{43}$$

and from (40),

$$\frac{k^2}{\delta} = \frac{13wl^4}{162EI} \tag{44}$$

Expressed as a fraction of the maximum deflection, we find

$$\frac{k^2}{\delta} = .642y_1 \text{ and } \delta = .4y_1$$

CANTILEVER OF UNIFORM SECTION, LOADED IRREGULARLY.

The deflection of the center of gravity of the load would be given by the formula

$$\delta = \frac{\int_0^l wydx}{\int_0^l wdx} \tag{45}$$

in which w is a variable.

The total work consists of two parts. One part is due to the flexure of the beam against its resilience, and the other part is due to the lowering of the center of gravity of the weight against the resistance offered by the resilience of the beam. In the case in question, where the support is considered rigid, these two parts are equal. The formula for the total work as set forth in books on mechanics may be written—

$$U = W\delta = \tfrac{1}{2}\int_0^l Mdi + \tfrac{1}{2}W\delta \tag{46}$$

Since $di = \frac{Mdx}{EI}$, formula (46) may be changed to read—

$$\delta = \int_0^l \frac{M^2dx}{WEI} \tag{47}$$

in which W represents the total weight.

This may prove more convenient for use than formula (45).

No formula for determining k^2 in terms of M direct seems practicable, so that k^2 would be obtained by first determining y, and then using the formula—

$$k^2 = \frac{\int_0^l wy^2dx}{\int_0^l wdx} \tag{48}$$

BEAM SUPPORTED AT ENDS.

FIG. 8, PLATE 59.

From the consideration that the period of vibration depends on the deflection of the center of gravity of a concentrated load from the position where the weight of the load is entirely unbalanced, it will be found that the period of vibration of a beam resting on two points of support and loaded at the center will be the same as a cantilever of half the length loaded at the end with half the load.

The period of a beam supported at the ends and uniformly loaded can be obtained as follows:—

Let w be the load per foot run, and L the length of the beam. The bending moment at any point B will be

$$M = \tfrac{1}{2}wL(\tfrac{1}{2}L - x) - \tfrac{1}{2}w(\tfrac{1}{2}L - x)^2$$

and

$$y = \frac{w}{2EI}\left(\frac{L^2x^2}{8} - \frac{x^4}{12}\right)$$

Making $x = \tfrac{1}{2}L$, the elevation of the point of support above the tangent at mid length (equal deflection at mid length) will be

$$y_1 = \frac{5wL^4}{384EI} \tag{49}$$

Applying formula (47), we have

$$\delta = \int_0^{\frac{1}{2}L} \frac{M^2dx}{WEI} = \frac{wL^4}{120EI} \tag{50}$$

since $W = \tfrac{1}{2}wL =$ load between mid length and end.

This gives the deflection of the center of gravity of the load in neutral position below the points of support.

We have—

$$k^2 = \frac{\int_0^{\frac{1}{2}L} w(y_1 - y)^2dx}{\tfrac{1}{2}wL} = \frac{w^2L^8}{E^2I^2} \times .00008542 \tag{51}$$

$$\frac{k^2}{\delta} = \frac{\frac{w^2L^8}{E^2I^2} \times .00008542}{\frac{wL^4}{120EI}} = \frac{wL^4}{EI} \times .01025 \tag{52}$$

Expressed as a fraction of the maximum deflection, we find

$$\frac{k^2}{\delta} = .7872y_1 \text{ and } \delta = .64y_1$$

Since $\frac{k^2}{\delta}$ varies directly as the load and becomes 0 when the load is 0, it is the deflection to be used in the formula for the period

$$T = \frac{2\pi}{\sqrt{g}}\sqrt{\frac{k^2}{\delta}}$$

By comparing this result with the period for a uniformly loaded cantilever of half the length, it will be found that the period of the cantilever is about 70 per cent as great.

BEAM UNIFORMLY LOADED, WITH SUPPORTS NOT AT ENDS.

FIG. 9, PLATE 59.

The formula for the bending moment changes at the point of support. For points outside of the support, the bending moment is given by the formula

$$M = -\tfrac{1}{2}w(\tfrac{1}{2}L - x)^2 \qquad (53)$$

For points between supports,

$$M = \tfrac{1}{2}wL(\tfrac{1}{2}L - A - x) - \tfrac{1}{2}w(\tfrac{1}{2}L - x)^2 \qquad (54)$$

By plotting these values, and integrating graphically for the values of i and y, formulas (34) and (35), we can obtain the deflections relative to the lowest point of the beam. By subtracting these values of y from y_s, the deflection of the point of support, we obtain the deflection relative to the points of support. Integrating graphically these latter in accordance with formula (45), we obtain the value of δ. If we square the deflections relative to the points of support, and integrate graphically in accordance with formula (48), we obtain the value of k^2. For points of support one-eighth length from end, $\frac{k^2}{\delta}$ works out approximately equal to

$$.0034\,\frac{wL^4}{EI} \qquad (55)$$

It will be noticed that for a uniformly loaded beam of half length $= l$, if supported:—At ends,

$$\frac{k^2}{\delta} = .1640\frac{wl^4}{EI} \qquad \text{from (52)}$$

At ⅛ length from ends,

$$\frac{k^2}{\delta} = .0546\,\frac{wl^4}{EI} \qquad \text{from (55)}$$

At mid length,

$$\frac{k^2}{\delta} = .0802\,\frac{wl^4}{EI} \qquad \text{from (44)}$$

BEAM IRREGULARLY LOADED, WITH SUPPORTS NOT AT ENDS.

This case can be solved by plotting the load curve, integrating for shear, and integrating again for bending moment. The process of obtaining deflections δ and k^2 would be the same as in the preceding case.

If the supports are not rigid, but are capable of movement, as for instance, a beam supported from balance arms with counterweights, a further complication will result.

MOTION IN A HORIZONTAL PLANE.

If a load W be applied at the end of a cantilever by small increments, a steady deflection δ will be produced. The work done may be expressed as $\frac{1}{2}W\delta$, and this is the measure of the resilience of the cantilever when deflected by an amount equal to δ. If a load $2W$ be similarly applied, the deflection will be 2δ, and the work done will be $\frac{1}{2} \times 2W \times 2\delta = 2W\delta$. This is the measure of the resilience of the cantilever when deflected by an amount equal to 2δ. Now let the load W be applied at once at the end of the cantilever. The work done at deflection δ will be $W\delta$, of which $\frac{1}{2}W\delta$ will be stored in the cantilever as resilience, and the remaining $\frac{1}{2}W\delta$ will represent the energy of motion of the weight W as it passes the point of steady deflection. It will be found that when the cantilever has deflected 2δ, and the resilience equals $2W\delta$ as shown above, the work done by falling of the load W is also $2W\delta$, and there is no energy of motion and the weight is momentarily at rest. But the weight W is not sufficient to hold the deflection at 2δ, and the resilience causes the weight to rise. As it passes the deflection δ, the energy exerted by the cantilever is $2W\delta - \frac{1}{2}W\delta = 1\frac{1}{2}W\delta$. The weight has been raised a distance $2\delta - \delta = \delta$ and the work done is $W\delta$. The remaining $\frac{1}{2}W\delta$ represents the energy of motion of the weight, which, it will be noticed, is the same as in the downward motion at the same point. It will be found that when the deflection is 0, the energy exerted will be $2W\delta$, and the work done in raising the weight will be $2W\delta$ also, and the load will be again momentarily at rest.

As has been shown previously, the period of this vibration will be the same as that of a simple pendulum of length δ. The period will remain unchanged when the vibration is reduced as the relation of velocity to length of travel of the weight is constant.

If the cantilever is turned on its side, and the load W is deflected by hand or some independent force to a horizontal distance δ to the right, the resilience will be $\frac{1}{2}W\delta$ as before when the deflection was in a vertical plane. If the weight be released, the energy exerted by the resilience of the beam when the weight passes the neutral position will be $\frac{1}{2}W\delta$, and as the weight is supposed to move in a horizontal plane, this will represent the energy of motion. When the weight has moved a distance δ to the left of neutral position, this energy will have been all expended, as the energy of resilience is again $\frac{1}{2}W\delta$, and the weight will be momentarily at rest. It will be noticed that the weight moves through a distance 2δ, and has an energy of motion at mid vibration of $\frac{1}{2}W\delta$, corresponding exactly to the motion in a vertical plane. The period in the two cases will therefore be identical.

DIPPING MOTION.

The amount of the dipping motion of a vibrating vessel can be obtained by considering that in the case of the "Rod in Tension,"

$$t = \frac{\pi}{2}\sqrt{\frac{\delta}{g}} \qquad (32)$$

The general formula for motion involving space, time and acceleration is—

$$s = \tfrac{1}{2}at^2 \qquad (56)$$

Substituting δ for s and the value of t in formula (32), we find

$$a = \frac{8}{\pi^2}g \qquad (57)$$

This shows that the average accelerating force is $\frac{8}{\pi^2}$ times the maximum accelerating force.

For the vessel of Plates 56 and 57, the "load" is 2,100 tons, and the weight to be raised or lowered is 15,700 tons. The accelerating force would be 2,100 tons if amplitude of vibration were such as to straighten out the deflection. Taking t as .197 second, corresponding to 76 vibrations per minute, and a as $\frac{210}{15700}g \times \frac{8}{\pi^2}$, corresponding to an amplitude of vibration in each direction of one-tenth of the deflection, we find from formula (56) that $s = .00678$ foot.

DISCUSSION.

THE CHAIRMAN:—Gentlemen, the paper is ready for your discussion now, and I trust you will not be unduly frightened by the mathematical characters which you find liberally sprinkled throughout the paper. The Chair will take advantage of his position to refrain from further comment.

MR. A. SCHEIN, *Visitor*:—Mr. Gatewood speaks about the primitive method which was introduced in measuring the vibrations on the tested steamer. That is why I wish to mention the fact that Mr. Elmer A. Sperry has recently completed a pallograph for measuring the vibrations of ships, for the use of the U. S. Navy engineers and also at the Model Basin, at Washington, D. C.

Briefly, the pallograph is an instrument which simultaneously records vertical and horizontal transverse vibration. Of equal importance is the introduction of pencils for indicating revolutions of the ship's shafts for each propeller separately, and prime mover, indicating seconds.

When the pallograph is in operation the pendulum appears to oscillate and vibrate rapidly, whereas in reality it is standing absolutely still, as the ballistics of the apparatus is so adjusted as not to be in synchronism with the vibration of the ship. The apparatus, which weighs hardly ninety pounds, can be placed in any part of the ship so as to detect the cause and location of vibration. The pallograph could doubtless be procured either from the officers of the Navy or from Mr. Elmer A. Sperry.

Mr. Francis B. Smith, *Member:*—I just want to make a few remarks based on some practical observations of vibration on ships of the class we have on the Lakes—long ships, about 600 feet long, 60 feet beam, and about 32 feet depth. We sometimes get reports of a ship vibrating very badly, and we have had occasion to try to locate this difficulty. We have not found any cases yet on our ships where we could not take the vibration out—that is, all perceptible effects of the vibration—by regulating our engines and the trimming of the ship with water ballast; it is very seldom that we have to go to the water ballast unless we find it has been improperly distributed.

We have had a number of cases where we have had men who made a profession of balancing engines go with us, and in following out their recommendations we probably have improved the trouble somewhat, but it has been our experience, in our class of ships, with the machinery and boilers located away back in the stern, where it is probably difficult to place them, that we are generally able to bring it down to a point where it does not do any injury to the ship, simply by balancing the engine in regulating the cuts of the different engines. That has been our experience.

Captain Albert P. Niblack, U. S. N., *Vice-President:*—I wish to make a few remarks merely on the importance of the question of the vibrations on board a battleship. The question is of vital importance, because the period of vibration of ships being necessarily different, it is quite conceivable that in a formation of battleships, the speed at which the formation is steaming might commit one ship to a vibration that was ruinous, in the fact that the vibration might disturb all observations of any kind—for instance, of range finding, gunsights, and fire control. The question is really with us a very vital one.

With a merchant ship you can take the necessary precautions to change the speed, but when you are in formation, as in the case of battleships, you cannot change the speed, and the admiral in command of a fleet possibly does not know that the other ship is vibrating. I want to bring up the point that probably by regulating the ballast by using trimming tanks, the vibration could be regulated even on a ship that found herself in this unfortunate position.

The helpful point that has been brought out by this paper is the practical application of a remedy and I thank Mr. Gatewood for it.

Captain W. S. Smith, U. S. N., *Member:*—The Department recently conducted some experiments of vibrations on battleships, and being familiar with them, I will state practically what has been done and some conclusions reached.

In the case of the Minnesota, a battleship which suffered a great deal through the breaking of shafts, a Board was appointed and the subject very thoroughly gone into. Experiments were made, and the machinery was put in perfect alignment so as to eliminate as much as possible any question of engine vibration by being out of line. The vibrations were measured, and the general determination reached was that stiffening, particularly under engine foundations, and with a due regard to the design of the shaft to make it heavy enough, would obviate the trouble—that is briefly the conclusion arrived at in the study of vibrations recently made. The question of thrust bearings was gone into, and they were supposed to be very thoroughly stiffened up through the inner bottom.

Mr. Luther D. Lovekin, *Member:*—I ask Captain Smith if the question of the four-bladed propeller did not have an effect on the vibration of the vessel?

CAPTAIN SMITH:—That is believed not to have had a very great deal of effect. That has not been thoroughly worked out yet, but it is not taken into serious consideration. As I understand, they will reinstall the three-bladed propellers instead of the four-bladed propellers.

MR. LOVEKIN:—I had the pleasure of talking with Captain Dyson the other day, and he informed me that the vibrations had been materially reduced, to his amazement, that the power had exceeded the old three-bladed screw, at 3,000, and that he would recommend that the three-bladed screws be put back to take care of the vibration.

CAPTAIN SMITH:—Mr. Lovekin evidently has later information on the subject than I have.

THE CHAIRMAN:—The Chair was about to remark that certain intimations have come to him somewhat at variance with the conclusions reached by Captain Smith. It appears to the Chair that it would be very desirable to have in the Society's Transactions the actual conclusions of the Board recently appointed by the Navy Department to consider thoroughly the subject of propeller shaft fractures, and I trust that will be accomplished before our next meeting. I understand that some of the results of their investigations were exceedingly interesting and show conclusively where we may look for these troubles. As I am not fully informed personally as to the details, I would prefer to hear from those who have had direct touch with the matter in its latest phases. I have no doubt that Captain Smith's information is based quite correctly on some of the preliminary work of the Board. It may be possible, however, in the final conclusions, based on results obtained from complete experiments, that there may be some modifications.

MR. JOHN REID, *Member:*—In the case of the Mauretania, about a year after she came out, they changed from three-bladed to four-bladed screws, which greatly reduced the vibration and changed the whole nature of the vibration. I used to go into the tunnel very often to see what was happening, and if you went close to one of the two aft screws you always found a curious action going on, especially in stormy weather, and that was the thrashing of the water against the ship's side, abreast of the screw, seemed to grow. The screw would go around freely for a few revolutions, and then there would be a crash of water against the side of the ship that seemed to grow larger and larger and then stop. I think that was a matter of torsional vibration of the shaft, but do not know enough about the subject to go into it from a mathematical point of view. I know that the changing of the screw did make a tremendous difference. As to what it did with the speed, I think that was also improved.

THE CHAIRMAN:—The opinion of the Chair is that Mr. Reid has "hit the nail on the head," and that ultimate results of investigation will indicate that it was mainly due to torsional vibration of the shafts; but I think it is wiser to have the complete results of the investigations recently undertaken and then members can draw their own conclusions.

MR. FRANCIS B. SMITH, *Member:*—May I make another remark on the subject of vibrations. It may be of interest to some of you some time. We have had a couple of expe-

riences within the last few months where two of our steamers, of exactly the same size and the same engine power in each case, have broken off three propeller blades. They are single-screw, four blades to the screw. In the case of the first one they started up the engine and the vibration was so great that they worked the engine slowly and went back to port, about fifteen or twenty miles. They lay there until they got a diver to take off the balance of the blades and replace them with new ones, all of the blades being replaced.

In the other case the boat was just leaving Escanaba and had not got out of the harbor, when three blades broke off at once. Instead of stopping there they went on. The captain and the engineer decided that they could get along with one blade, which they did, and made almost as good time as they would have done with the four blades. (Applause.) The boat runs at about eleven miles an hour, as a rule, and they averaged better than nine miles an hour all the way down, average run. After they got going, and after the boat got some headway, there was very little vibration with one blade. The boat ran very steadily so that even in shallow water—in crossing Lake St. Clair, where the water is very shallow—she did not vibrate at all. I presume the depth of water had something to do with it. When she first struck Lake Erie, with the water a little deeper, but not very deep, she did vibrate, and they slowed her up for about fifteen miles, and then opened her up and went ahead full speed, turning up faster than the usual turning. I thought the matter might be of interest.

Mr. Elmer A. Sperry, *Member:*—That reminds me of the early history of the screw propellers. The screw went clear around the hub, and it was found, the more parts of this screw that were knocked off the propeller the better it became and the more speed could be made; but even though there was not much vibration experienced with the one screw under the conditions named, yet it practically left lagging pitch in the single blade, and that would give vibration.

When the Lusitania was on her trial trip her stern shook so as to be uninhabitable. That was true to such an extent that one would think that the stern rose and fell a foot. Of course the Lusitania was the proudest ship of England at the time, and England's great men were aboard on the trial trip in their dress suits each evening. When this vibration became apparent Sir William White used every possible means to get in touch with the great Dr. Schlick, of Hamburg, to come to the Lusitania with his pallograph and see if he could trace the source of the vibration. Dr. Schlick came, and I saw the doctor afterwards. He said it was the hardest work he ever did in his life. He had to appear at night in his dress suit. In a day and a half he had traced the vibration to one of the three propeller shafts. He had made a scratch line on the inside of the boat on one of the propeller shafts, and opposite that line, he told them, there was one wing of the three-bladed propeller that had two degrees leading pitch, and the vibration was due to this blade. They got the ship into the drydock and pumped it down so that they could expose that particular blade, then they put battens on, and the best they could determine was 1.8 degrees leading pitch, just as Dr. Schlick had said. They chipped it, and got it back into pitch equal to the other blades. At noon the next day they tested the ship again, and found that the vibration had totally disappeared. Sir William White told me that Dr. Schlick could have had anything in England after this achievement.

The Chairman:—Are there any further remarks on this paper, gentlemen? The further it goes, the better it gets. If there is no more discussion, we will call on Mr. Gatewood to make such reply as he desires.

MR. GATEWOOD:—The basis of the paper is that, by changing the lading of the vessel as a beam, the period of vibration is automatically changed. Now, in the case of the vessel with which I had experience we were unable to change the loading of the vessel. So what we did was to change the revolution of the engine. The trouble was with the synchronism of the period of vibration of the vessel to the revolution of the engine, and it would seem very natural with these lake vessels, very long and comparatively shallow, that their condition of lading should at times bring them into synchronism with the revolutions of the engine. But if propeller blades were broken off, so that the engine would run faster, that would also, it seems to me, account for the fact that the vibration would be thereby eliminated and you would get out of touch with the natural period of the vessel.

Of course the paper does not pretend to touch upon a great many things in connection with vibration. It treats just one phase of the subject, that is, the vibration in the vertical plane of the whole vessel. It does not pretend to take into consideration local vibrations. I have not attempted to touch that part of the subject and have not the experience to pass on it.

As to the question of modifying the vibration of a battleship by putting in water ballast, the effect of adding water ballast could probably be figured along the lines of the paper for the vibration of the whole vessel, but if the vibration is merely local, such as certainly occurs on a number of vessels (that is, you find it in one spot and you find it nowhere else in the vessel), nothing in the paper, it seems to me, would have any bearing on that phase of the subject.

The measurement for determining the vibration on the vessel which the paper illustrates was very crude, because it was for the vibration of the whole vessel, but I believe it was fairly accurate.

Those who have read the paper will notice that I adopted, for measuring the vibration, the scheme of measuring the extension and compression occurring in the stringer plate on the shelter deck of the vessel. That is to say, the vessel was treated as a beam, and as the beam changed its load due to the vibration the top member of the beam or girder stretched and shortened, and measurements were taken over a length of 90 feet so as to enable them to be caught by the eye. While, as I say, the method is crude, it really is about as accurate as could be obtained for the particular kind of vibration. It gave a very good measure of the change of stresses in the ship, and I was able to count the number of vibrations by hand, just as you can count the revolutions of an engine, the vibrations being in the neighborhood of seventy-six.

The vibration that is due to torsional vibration and irregularities of pitch of the propeller, it seems to me, would not cause the kind of vibration which is discussed in the paper. That is another phase of the subject which can very well be considered, if there is anyone here who has the means of presenting further data on the subject.

I remarked in opening that the introduction of the turbine was expected to eliminate vibrations, and that there was some disappointment because such was not the case. I think, however, that the type of vibration which is caused by the turbine is not the type of vibration which had been caused by the reciprocating engine; that is, it is not the vibration of the whole vessel, but of a part of the vessel—local and not general.

THE CHAIRMAN:—We will now proceed to the next paper, No. 9, entitled "Data on Hog and Sag of Merchant Vessels," by Mr. T. M. Cornbrooks, Member.

MR. CORNBROOKS:—This paper is simply an attempt to follow out the observations which were made some time ago on the naval colliers Orion, Jason and Neptune, and is really a supplement to the paper of Naval Constructor Smith in which he gave the result of experiments on those vessels. I do not know that there is anything very new in the paper, except that it rather fills out the previous paper and brings the data up to date. The principal object in writing it was in the hope that there would be some discussion from other yards, especially from the Lakes, in reference to the experience which has been had on these same lines.

DATA ON HOG AND SAG OF MERCHANT VESSELS.

By T. M. Cornbrooks, Esq., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

In a paper read before this Society in 1913, Naval Constructor S. F. Smith presented considerable data showing observations made on three navy colliers built by the Maryland Steel Company, to which was added the data of the two colliers built by the Newport News Company.

Since that time two additional colliers have been constructed for the Panama Canal. These colliers are of the same general dimensions as the Orion and Jason, but of increased deadweight capacity.

The Ulysses and Achilles, Panama colliers Nos. 1 and 2, are built from the same lines as the Orion and Jason, but to secure the necessary capacity for coal the machinery was moved aft 15 feet and the 'thwartship coal bunkers reduced 10 feet in length, making the holds 25 feet longer. The contract for these vessels required that they should carry 12,000 tons of cargo, 1,200 tons of bunkers and 105 tons of stores, feed water, crew and effects, on a draught of 28 feet 1 inch. As a matter of fact they drew 27 feet 8 inches when loaded with the above deadweight.

Following the methods used in securing the data on the previous colliers, we started by establishing a datum line by transit while the vessels were on the stocks and supplemented this by readings taken immediately after launch, when machinery was installed, when in dock, before loading and when fully loaded.

These curves are shown on Plate 60. It will be noted that when fully loaded the Ulysses sagged $2\frac{1}{8}$ inches and the Achilles $2\frac{1}{16}$ inches from the original datum line, as compared with $3\frac{7}{8}$ inches on the Neptune, $2\frac{15}{16}$ inches on the Orion and $3\frac{3}{16}$ inches on the Nereus. The difference in the amount of sag between the Orion and Jason and Ulysses and Achilles can probably be accounted for by the better distribution of cargo.

It will be noted that two curves are shown of the Achilles, of the ship completed, *i. e.*, May 10 and 20; these observations were taken under the dates noted to determine the deflection while the forward oil tanks and double bottoms were filled with water as itemized, in preparing for a test of the oil pumping capacity.

The results show considerable hogging effect when compared with the Ulysses when completed under date of March 15, which can be accounted for by the different conditions of tank loadings.

In addition to the curves taken on the Orion and Jason, observations on the Achilles were taken, as shown by curves on Plate 61, for determining the deflection of the hull in way of the forward oil holds, when under hydrostatic test.

No. 1 starboard and No. 4 port holds were filled with water to the second deck with the pipe column to the upper deck 8 feet above. Measurements were taken before, during and after tests at ten stations on the starboard side, spaced approximately 10 feet each, starting 10 feet forward of forward bulkhead No. 112 of hold No. 1 and extending 30 feet aft of after bulkhead No. 106 of hold No. 4, the distance between forward bulkhead of No. 1 hold and after bulkhead of No. 4 hold being 50 feet. With the exception of the three forward stations which were in the way of the planked-over portion of the building ways, a stake 3 inches square by 30 inches long was driven flush with the ground and a tack driven flush in the head of the stake and on the planking on the ways. A corresponding center punch mark was made on the hull above; the height at these points or stations was carefully measured with the results herein noted.

Provision for carrying the extra weight during the test was made by fitting (in the way of tested compartments) additional keel blocks adjacent to the regular ones; also additional shores between the regular shores. Extra cribbing was also provided under bottom between keel blocks and bilge shores.

The total bearing of keel blocks, shores and extra cribbing amounted to approximately 480 square feet. The weight of the ship for 50 feet at 12 tons per foot was estimated at 600 tons. The weight of water in No. 1 and No. 4 holds was estimated at 743 tons, this making a total of 1,343 tons, or a bearing pressure of 2.8 tons per square foot.

In checking the measurements during the test, with tanks filled, the following deflection was observed at the various stations (starting forward) under the dates noted:—

	Dec. 29, 1914	*Jan. 4, 1915*
Station No. 1	1/16″	1/4″
Station No. 2	1/8″	1/4″
Station No. 3	1/8″	3/16″
Station No. 4	5/16″	3/8″
Station No. 5	5/16″	5/16″
Station No. 6	1/16″	1/16″
Station No. 7	3/16″	3/16″
Station No. 8	1/8″	1/8″
Station No. 9	1/16″	1/16″
Station No. 10	1/16″	3/16″

Check measurements were taken January 14, 1915, at the various stations after tanks were emptied, which showed the ship to have settled from the original measurements taken December 21, 1914, before tanks were filled, as follows:—

	inches		inches
Station No. 1	1/8	Station No. 6	0
Station No. 2	1/16	Station No. 7	1/8
Station No. 3	1/8	Station No. 8	1/8
Station No. 4	1/8	Station No. 9	1/16
Station No. 5	0	Station No. 10	1/16

The difference in the above measurements can be accounted for by the variations in fitting packing, cribbing and shoring under the ship. It would be fair to assume that all the packing, cribbing and shores would not be wedged up or fitted uniformly to exactly the same reactive pressure and the ship when under test would naturally deflect the least where the reactive pressure was the greatest. This is evidenced by reference to the check measurements above, taken January 14, 1915, showing no permanent settlement at stations No. 5 and No. 6 and 1/8-inch settlement at station No. 7, which can be accounted for as noted in the foregoing regarding fitting of packing, etc.

It was in way of stations 4, 5 and 6 that the extra cribbing was provided having a ground bearing area of 104 square feet.

Allowance must also be made in a test of this character for initial settlement where a heavy load is applied.

It would add considerable interest to the data given in Mr. Smith's paper and this addition, if some of our Lake members could present data of their observations on the usual Lake type in the discussion.

In a discussion before the Institution of Naval Architects in London on March 24, 1915, Mr. French stated that some of the Lake vessels were sagged as much as 10 inches, which would appear to be excessive.

DISCUSSION.

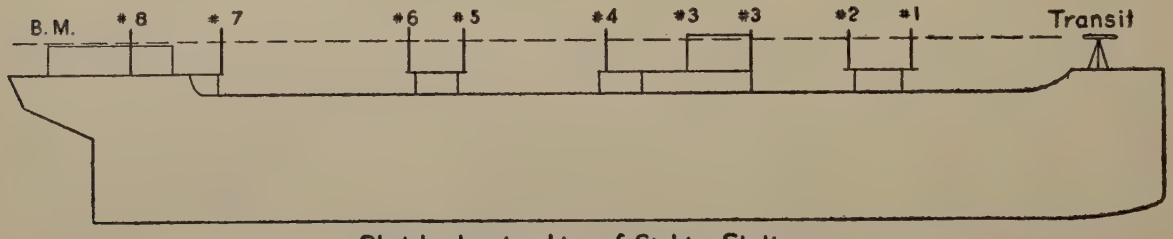
THE CHAIRMAN:—The paper on "Data on Hog and Sag of Merchant Vessels," by Mr. T. M. Cornbrooks, Member, is now open for discussion.

PROFESSOR H. A. EVERETT, *Member:*—I think with reference to papers of the character of those by Mr. Cornbrooks and Mr. Gatewood, that the value of such work largely lies in the possibility of tying in the theoretical calculations for deflections with the actually measured deflections under conditions where the load is known, and in that connection we recently did some work, which, perhaps, will be of interest, on the large freight steamers Atlantic and Pacific, built at Fore River. These vessels were not quite as large as the one Mr. Cornbrooks speaks of, but I will give the dimensions later. In carrying out the work our primary object

was to measure the deflection under different conditions of load, then make the customary strength calculations, knowing the lines and the character of the loads, and see how they actually tallied with the computed deflections.

Before starting the work it seemed that there might be a question of temperature affecting the problem, especially as our attention had been drawn to that fact by an earlier paper, which called attention to the noticeable change in form, due to variations in temperature, in torpedo boats. It was decided to investigate that first. The manner in which the investigation was carried out was to take the vessel afloat, and to take continuous readings of deflection throughout the day, measuring the temperature of the water, the temperature of the deck, and measuring the deflections, in much the same manner as indicated by Mr. Cornbrooks.

The boat on which we made these experiments was the Atlantic, and her dimensions were 388 feet between perpendiculars, beams 54 feet 4 inches, and mean draught 24 feet. She had a depth of 31 feet 3 inches. The general character of the boat you are perhaps familiar with. I will make a crude sketch of it here on the blackboard.



Sketch showing Line of Sight + Stations.

The machinery was aft (indicating on blackboard), having a large open space for cargo throughout the central part of the vessel; we had a transit set up on the forecastle and sighted to eight stations down through the entire hull structure. The transit was guarded to make sure we could recover our original position, and deflections were noted in this way.

Experiments were made on two days and they were started very early in the morning. The work was in conjunction with some thesis work of Messrs. Bortner, Gordon and Ramsey, who carried out the actual observations. They arrived shortly after three o'clock in the morning and took continuous observations for deflection throughout the entire day, at about half-hour intervals. The temperature of the water and temperature of the deck were obtained by means of small thermometers plastered on the deck and hung into the water alongside. I do not think we are interested in any other part than the maximum deflection, which occurred shortly aft of midships.

If you will permit me to make this brief table, it will clearly show what occurred.

S. S. "Atlantic," June 7, 1914.

Time	Deflection at Station 5	Temp. Diff. t, Deck—t, Water	Time	Deflection at Station 5	Temp. Diff. t, Deck — t, Water
4.30 a. m.	.00 foot	—9° F.	10.30 a. m.	.12 foot	+39° F.
5.30	.01	—5	11.30	.12	+38
6.30	.02	+7	12.30 p. m.	.13	+40
1.30	.05	+21	1.30	.14	+41
8.30	.05	+32	2.30	.13	+34
9.30	.09	+38	3.30	.11	+33

Maximum deflection = 0.15 foot between 1.30 and 2.30 p. m.

It was a warm day—this was on the 7th of June—and the temperature difference between the water and the hull ranged from .9° F., when the hull structure was cooler than the water at 4.30 a.m., to plus 7° F. at 6.30 a.m.; at 8.30 a.m. it was up to 31° F., practically 32° F.; at 10.30 a.m. to 39°, at 12.30 p.m. it had gone to 40°, at 2.30 p.m. to 41°, and at 3.30 p.m. it had begun to drop off down to 33°.

Now the deflection in hundredths of a foot, under these conditions, counting from the starting point as zero, and continually increasing to the maximum, had these values: The first two hours showed practically no change; at 8.30 a.m. it had gone up to .05 of a foot, at 10.30 a. m. it had gone .12 (this was plus), at 12.30 p.m. to .13, at 2.30 it was .13, with a crest in between of .15, which is the interesting part, and at 4.30 it had dropped to .11.

That was very interesting, and before we carried our final conclusions through it was obviously necessary to take account of deflections due to temperature difference. The result was that if we neglected temperature difference, when checking the theoretical deflection calculations with the observations, the results were erratic. If we took account of temperature conditions and corrected our observations (made for different conditions of loading and extending through a number of months), to reduce them to a standard temperature basis, we got a series of corrected deflections which tallied in with the theoretical results. That was interesting, and I think it was helpful.

The point is: Here we have deflections due to temperature of .15 foot. That is something over 1⅝ inches or 1¾ inches, perhaps. We are dealing with total deflections in most cases of about 3 inches. I think that Mr. Cornbrooks' deflections are of about that same order, and if we have the possibility of temperature variations injecting such a change as this in the observations of deflections, it would seem that it would be desirable to have them accounted for.

I think it would be a great help to us and add to the value of the paper if Mr. Cornbrooks would include in his statement any temperature data which was available, and also the time interval which elapsed between the different observations, because from this table you will notice as soon as the temperature begins to drop the deflection also begins to decrease, but where the observations were taken at half-hourly periods it showed that the deflection did not drop until the temperature drop had taken place; that is, the deflection of the whole structure lagged behind the temperature change.

PROFESSOR W. SELKIRK OWEN, *Member:*—In connection with temperature deflection, I had occasion to notice the deflection in the collier Cyclops at Cramp's. That, as we know, is a large single-deck vessel, and the upper deck, being unsheathed, is exposed to the temperature of the elements, etc. The way attention was first directed to it was when the vessel was fitting out and lying at the builder's dock. It used to be the practice of the staff in the draughting office to go down and take readings of the draught to check up the weight going on board the vessel. We noticed there was an erratic variation from day to day in the mean draughts obtained from reading the draught marks on the ends of the vessel. The draughts were measured by a man in a boat alongside the ship. The water in the Delaware is never quiet; there are changes of density in the water, too, and tide and currents, etc., but even at that the indications were so erratic that it was thought the temperature might have something to do with it. Following several cool days in the summer we took draught readings on the ends of the vessel, and then in the middle of the afternoon, which seemed to be the hottest time of the day, we took similar readings again, and the mean draughts were decidedly different. Something was going on. The ship was being completed and without interfering with the work on deck we undertook to see if we could trace this variation, so we took about six stations along the length of the ship, and got the carpenters to measure down on the outside of the vessel from the deck line with battens while she was floating in the water and put draught works on the ship's side. This was done on both sides of the ship. Draught readings on all these stations were measured at four o'clock one morning, following several cool days, and about two hours later on, but there was practically no change. They were measured again at three o'clock of the same day, when it was quite hot, and we saw this tendency to hog the vessel, due to temperature, which indicated itself by an otherwise straight water line on the ship becoming a fair curve, with relation to the water surface. Of course our method was crude for actually measuring the points. It was clearly defined. It went to show that the tendency existed, and we laid down the curve, and there was a matter of 5 inches springing in the straight line of the ship. It was submitted to the naval constructor at the time, and he allowed 2 inches to be deducted from the mean draught of the ship obtained by readings from the ends of the vessel; thus the contractors were allowed that consideration for change of form due to temperature in making the weight of the vessel for their contract displacement.

MR. ELMER A. SPERRY, *Member:*—There is evidence of lateral deflection, too, in cases of the sun on one side of the vessel and the other side in the shade. We recently had an opportunity to determine that in a long base range finder, where our stations were 444 feet apart and the vessel immersed and floating, and exposed all day on the south side. These stations were equipped with apparatus by which we could read to less than the half of 1/1000 of a degree. We found the maximum deflection to be about .015 degree. This makes no difference with the range finder as it is provided against this contingency. But we see that there is a lateral deflection also due to temperature.

COMMANDER F. L. SAWYER, U. S. N. (Retired), *Member:*—It will be recalled that Naval Constructor Smith read a paper before the meeting of this Society in 1913 on the subject of the alterations in the deck lines of a collier after launching. In the discussion at that time one of our members, Mr. F. B. Smith, the chief engineer of the Pittsburgh Steamship Company, related the difficulties which his company experienced in loading their large fleet of

ore carriers on the Great Lakes on account of the fact that alterations of draught occurred between Duluth or West Superior and the Sault Ste. Marie canal of as much as six or seven inches, so that it was necessary to allow for this change after loading in order to be able to pass through the canal, and invited suggestions from the Society for some remedy. Different methods of loading the various hatches had been tried without success. It occurred to me at that time that probably the extraordinary changes in draught could be accounted for by the changes in temperature, and the abnormal temperature differences between the keel and upper deck that exists in the season of open navigation on Lake Superior. It is generally known that the waters of Lake Superior are extremely cold even in summer. A long ore vessel passing down the lake from April to October would be in effect a box girder of some 600 feet in length, about 32 feet in depth, with the lower member in a temperature of perhaps 40° F., and the upper member, especially when exposed to the rays of the sun, a great many degrees warmer. Applying the coefficient of expansion of steel to this girder, it was seen at once that a draught change due to hogging of half a foot or more could be easily accounted for. I suggested to Mr. Smith that a remedy ought to be found by playing the cold water of the lake over its deck and top sides of these ore vessels by using their deck hose a sufficient time before arriving at the canal. Mr. Smith now informs me that this simple remedy was applied and proved a cure for their trouble, and that they are able to load the ore carriers half a foot deeper in consequence.

When the fact is considered that more than forty million tons of ore are now passed through this canal each season, an increase of even two to three per cent is a considerable item.

It seems an opportune time to call attention to the considerable effects which may be produced in a ship's structure by temperature differences in the hull, not only for commercial and navigational purposes, but possibly for its effect in gunnery. The salvos of a battleship are "bunched" only after the most accurate and delicate bore sighting and adjustment. Any warping in the hull thereafter would necessarily increase dispersion to some extent. Range finding would be affected from the same cause.

Mr. Cornbrooks:—The data which Professor Everett has given with reference to the Atlantic and Pacific are of considerable interest in connection with this paper, and I am sorry that we have omitted to give the temperature of the water and of the deck at the time these observations were taken. I will endeavor to secure these and add them. You will note, however, that on each curve the date on which it was taken is given.

In the original paper by Constructor Smith we took some observations early in the morning (8.30 a.m.), and during the heat of the day (2.30 p.m.) on the Neptune, which showed, I think, about ⅞ inch difference, for somewhere near 7 degrees difference in the temperature. I am not sure of that difference in the temperature—that sounds like a rather big difference in temperature—but at that time we did not take any observation early in the morning or during the middle of the day. Those experiments were simply carried out in order that we might secure the benefit of any sag when it came to loading the vessel for a trial trip, and accomplished these results.

I am sorry there are no data available for these long, shallow vessels which are used on the Lakes. If you will note in the last paragraph in the paper there is reference to a discussion before the Institution of Naval Architects in London this year, in which Mr. French said that some of the Lake vessels were sagged as much as ten inches, which would

appear to be excessive, to use his language. That remark went unchallenged in the meeting in London. It may be so, but it does not sound as though it is correct.

Mr. Francis B. Smith, *Member:*—I can say that is not correct. We found a difference of about 6 inches on 600-foot steamers. As has been remarked, by turning on the hose, starting at Whitefish Point, about forty miles above the "Soo," and keeping it on and cooling off the upper part of the vessel, the vessel would straighten out, so that when she got down to the "Soo" locks she went through all right.

The Chairman:—There might be some who would cavil at taking temperature observations, and be disposed to be skeptical as to temperature having much practical influence; but after hearing the remarks of our friends from the Lakes, indicating that they can change the draught of a vessel as much as six inches by playing a hose on the deck and reducing the temperature, I think that practical men will admit that temperature differences are very important and that the figures relating thereto may be accepted as reliable.

Mr. Smith:—For fear the remark I made may give a wrong impression, I will say that starting out our vessels were loaded to the full capacity of the canal before they left, and when they got down to the locks they could not get through, because they were drawing about six inches more water forward and aft than when they left the head of the lake. By straightening them out, they were put back in position so that they could get through.

Mr. Cornbrooks (Communicated):—I transmit herewith the official weather bureau reports for the dates and times given, as suggested by Professor Everett:—

No. 144.

December	12–14,	12	M., 37° F., clear.
		2	P.M., 36° F., partly cloudy.
March	15–15,	3	P.M., 50° F., clear.
April	6–15,	11	A.M., 63° F., cloudy.
April	10–15,	1	P.M., 79° F., clear.

No. 145.

February	6–15,	10	A.M., 35° F., cloudy.
February	8–15,	9	A.M., 28° F., partly cloudy.
May	10–15,	3.30	P.M., 68° F., clear.
May	20–15,	3	P.M., 63° F., cloudy.
June	1–15,	11	A.M., 66° F., partly cloudy.
June	4–15,	3	P.M., 70° F., cloudy.

The Chairman:—I am sure the Society desires to express its appreciation to the author of this paper, Mr. Cornbrooks; and also to the author of the preceding paper, Mr. Gatewood, for their most interesting and valuable contributions.

We have now reached the end of our morning program, and we will adjourn until two o'clock this afternoon.

FOURTH SESSION.

FRIDAY AFTERNOON, NOVEMBER 19, 1915.

President Thompson called the meeting to order at 2.15 o'clock.

THE PRESIDENT:—The Council proposes to submit certain names for membership, and the Secretary will please read the names.

SECRETARY COX:—At a meeting of the Council held at the close of the morning session, the following candidates were passed upon and recommended for election as follows:

For Members:

Edwin C. Bennett, Naval Architect, Fore River Shipbuilding Corporation, Quincy, Mass.

Frank W. Chambers, Superintending Engineer, Talbot Boiler Company, 120 Liberty Street, New York, N. Y.

For Associates:

William T. Sitt, Vice-President and Chief Engineer, General Erecting and Improvement Company, 9 East 40th Street, New York, N. Y.

T. Arthur Frey, General Manager, General Erecting and Improvement Company, 9 East 40th Street, New York, N. Y. Postoffice Address, 157 West 21st Street, New York, N. Y.

For Juniors:

Ralph M. Smith, Draughtsman, Electric Boat Company, New London, Conn.

Felipe Altamiranos, Graduate, Marine Engineering School, The Chilean Navy, now senior student, University of Michigan, Ann Arbor, Mich. Postoffice Address, Box 166, Ann Arbor, Mich.

THE PRESIDENT:—You have heard the names offered for election by the Council. As many as are in favor of the election of the gentlemen named, make it manifest by saying "Aye;" contrary-minded, "No." It is a vote, and the gentlemen are elected.

We will now proceed with the regular order of business, which is the presentation of paper No. 11, entitled, "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by Messrs. W. J. A. London and Frederick D. Herbert, Members.

MR. HERBERT:—In presenting this subject for your discussion, I will say that we have simply endeavored to give you a little of our own experience and endeavored to refer you to papers which have been read beforehand on relative subjects. There is nothing particularly new in the adoption of the turbine for generator work. There has been some development of the turbine for pumping work, but on force draft it is quite a new field, as a few years ago there were no fans applicable for direct connection that we knew of, and there our marine work has really made the first step in direct-connected force draft problems.

THE APPLICATION OF SMALL STEAM TURBINES FOR AUXILIARY PURPOSES ON BOARD SHIP.

By W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

INTRODUCTION.

In the early stages of development of the land turbine the possibilities of the small turbine for auxiliary drive, etc., were almost entirely overlooked, due to the concentration of energy towards the perfecting of the larger machine. The small turbine, of course, had to come and is now a well-established, and in fact a standard, prime mover for the great majority of auxiliary apparatus.

In marine work we have seen the gradual elimination of the reciprocating engine for practically all classes of work by the turbine, land practice is repeating itself here, and the possibilities of a small turbine for auxiliaries on board ship are now demanding attention of all marine engineers.

It is interesting to note in passing that while the small turbine is considered a comparatively new innovation here, the earliest turbines built by Sir Charles Parsons were used for lighting purposes on board ship. In fact, the majority of the first machines built were used for this work.

The small weight due to the high speed permissible in the generators at that time appealed to the Government and private shipbuilders alike, and having made such a good start it is rather surprising that this application did not become more universal.

In a discussion on the Electrical Equipment of Ships before the I. E. E., April 5, 1900, Mr. A. A. Campbell Swinton gives some interesting particulars regarding their early installations, as follows:—

"* * * I was perhaps the first to put turbines for electrical purposes on board a warship—in the case of the Blanca Encalada, which was sunk in the Chilian War.

"During the period I was at Elswick we put a large number of turbines into warships, and they worked exceedingly successfully. After that the Admiralty adopted them, and in a conversation with Mr. Parsons, whose turbines they employed, I asked him to what he attributed the fact that the Admiralty did not continue to use them. We discussed the matter, and we agreed as to the reasons. First of all, steam turbines are not well suited for the small powers such as were then used in ships, as it is very difficult to make small turbines economical. When you

get to the larger sizes it is of course a different matter. Another thing was that, in those days at any rate, the electrical part of the equipment of a ship was a very small proportion of the whole, and it was difficult to get the engineers to take sufficient pains to learn the details of a new machine which they only considered a very small part of their business. Thirdly, in some cases, these turbines were placed transversely, across the ship, instead of being placed longitudinally, as they should have been. With turbines placed transversely, and running at very high speeds, there is a very heavy strain and danger of injury to the turbine, owing to gyroscopic action when the ship rolls. * * *" (See Journal Institute Electrical Engineers (England), Vol. XXIX, p. 612.)

Among the earlier ships fitted with turbo-generators were the Earl Percy, City of Berlin (Atlantic liner) and several battleships of the Benbow type—all about the year 1888 (Plate 62).

Among the earliest applications was the particularly interesting portable plant designed for operating the searchlight of ships passing through the Suez Canal, very few ships in those days being equipped with any electrical plant.

The small high-speed turbo-generator made an ideal machine for this purpose and was installed in a cage or crate with a projector which was hoisted on board at one end of the canal and coupled up by a flexible steam hose on deck, and the whole apparatus removed at the other end of the canal.

In 1894, the first turbine-driven forced-draft fan was installed on a yacht built by Ramage & Ferguson at Leith, and one or two sets were tried out on British torpedo-boat destroyers, but owing to the combination considered necessary at that time for high efficiency, namely, the high-speed turbine and screw type of fan, the noise of the fan made its universal application prohibitive.

TURBO-GENERATING SETS.

The turbo-generator has become practically the standard unit for electrical production in all navies and merchant marine, so that little need be said about this application at the present time. (Plates 63 to 72 inclusive show some characteristic types of modern turbo-generators for marine work.) It might be interesting, however, in passing to quote the views of Mr. Horner in his paper before the recent International Convention at San Francisco:—

"As will be noticed subsequently in small vessels and freight steamers, where the sets are of small capacity, say from 2 to 20 kilowatts, the prime mover is a reciprocating engine. This unit possesses distinct advantages of operation from the practical side, as such ships cannot carry an engineer expressly for the care of the generating plant (page 1521).

"Sets to exhaust into feed-water heater, main or auxiliary condenser, or to the atmosphere. Condensing or non-condensing with approximately 8 to 10 inches

back pressure. It is probable, because they are usually exhausted into the feed-water heater for steam economy, that greater stress is not laid upon the efficiency of the prime-mover (page 1521).

"Small direct-connected turbine generating sets have been employed on shipboard *and in certain installations have given satisfaction,** but opinion among owners differ as to the advantages of the turbine over the reciprocating engine. Many marine engineers object to the high rotative speeds for direct-current generators and the lack of economy unless a high vacuum can be provided. On the other hand, some engineers prefer the turbine drive because of the reduction of upkeep and ease of operation.

"The use of reduction gears between the turbine and generator is now being suggested. In this set the water rate will doubtless be greatly reduced approximately 10 per cent, and the speed of the generator can be brought down to reasonable limits with high speed on turbine. Although such sets have been installed, no service data are available for comparison or comment. These sets, however, have shown, as expected, a great reduction in weight and water rate" (page 1522).

Mr. Horner is not an enthusiast for the turbine, but, as mentioned above, the increasing adoption of the turbo-generator in lieu of the reciprocating set would naturally indicate that the past performance of these machines is better than stated by Mr. Horner in the quotation in italics cited above, viz., "that in certain installations have given satisfaction." The really interesting phase of the small turbine situation today, however, is in the wider application of this machine.

GENERAL APPLICATION.

The small turbine is now successfully employed for the following purposes:—

1. Generator sets.
2. Wireless sets.
3. Forced draft blowers.
4. Circulating pumps.
5. Hot well pumps.
6. Ash ejectors.
7. Induced draft fans.
8. Ballast and service pumps.

*The italics are ours.

The three new battleships, the Arizona, Mississippi and Idaho, are being equipped with turbine auxiliaries as follows:—

Type	Arizona						Mississippi							Idaho					
	No.	Steam press	Back press	Speed R.P.M.	B.H.P.	D. C. or geared	No.	Steam press	Back press	Speed R.P.M.	B.H.P.	D. C. or geared	No.	Steam press	Back press	Speed R.P.M.	B.H.P.	D. C. or geared
		lbs.	*lbs.*					*lbs.*	*lbs.*					*lbs.*	*lbs.*			
Dynamo condenser pumps	....	.....	.....	.....	.....	.....	2	295	26	1275	15.8	D. C.	2	200	26	1275	14.4	D. C.
Boiler feed pumps	2	250	15	3000	180	D. C.	3	295	15	3000	144	D. C.	3	230	15	3000	174	D. C.
Forced-draft fans.	12	250	15	1550	32	D. C.	.....	.....	.....	.....	.....	.....	9	250	10	1550	46	D. C.
Main circulating pumps	....	.....	.....	.....	.....	.....	2	265	20	3620 850	460	Geared	2	230	5	1350	347	D. C.
Distiller circulating pumps	....	.....	.....	.....	.....	.....	2	295	8	2000	13.2	D. C.	2	250	8	2000	12	D. C.

BLOWERS.

Apart from generator sets the first serious application in the U. S. Navy of the small turbine was forced-draft sets on torpedo-boat destroyers. The great importance of the successful and continual operation of this apparatus, the serious losses that had been sustained by the breaking down of engine-driven fans on trial trips and in service, made the Government and shipbuilders seriously consider the possibilities of some other form of drive that would be more reliable.

Motor drive was impracticable, and the steam turbine, therefore, presented the only feasible solution provided a machine could be designed giving a reasonable economy with a mechanical design that would insure absolute reliability.

The next step, namely, economy, was easily demonstrated. A deputation consisting of Capt. C. W. Dyson, Rear-Admiral Little, Captain Higgins of the U. S. Navy Department, and representatives of practically all the shipyards visited the works of the Terry Steam Turbine Co. on June 15, 1909, and conducted exhaustive tests on a standard horizontal turbine with the same diameter of wheel that would be used for a vertical turbine of the same power (see Transactions American Society Naval Engineers, Vol. XXI, No. 3, August 1, 1909).

The economy proved satisfactory. The next step was the satisfactory mechanical design.

The first design submitted to the Navy Department by the writers for a forced-draft unit was a horizontal turbine, geared to vertical fan shaft, thus permitting the use of standard type of turbine running at high speed with resulting good water rate. However, the Bureau preferred to sacrifice economy for reliability, and requested that the design be modified to a direct-connected vertical-shaft unit, thus cutting down the weight and removing possible trouble at the gear.

This led to the design and adoption of the Terry type BV which for many years has been standard in the U. S. Navy (Plate 73).

As in all other turbine development work since the very first the trouble was not at all serious as far as the turbine itself was concerned, but in the design of a satisfactory driven member.

At the time of which we are writing, there was no fan developed for turbine speeds to give the required volume (23,000 cubic feet per minute) at the low head necessary of only 5 inches with an open type of fan, the cased type being prohibitive. Also, the screw type of fan could not be considered on account of the noise. Several fan-makers tackled the problem and did not appreciate what they were up against, and it is interesting to note the lack of knowledge that existed in this branch of engineering at that time. The first fan was guaranteed on paper to run at 2,500 revolutions per minute and require a horse-power of 30. After several very disheartening attempts at procuring a reliable fan, a successful fan was finally built, but the speed had by this time been dropped to 1,700 and the horse-power had gone up to 60.

The efficiency of the first fan was in the neighborhood of 25 per cent. By

careful study and experimental work by the fan-builders, this has been increased to 50 per cent at the present day.

The main difficulties lay in the design of a low-head fan without casing. In other words, the old turbine propeller problem was again present. The fan, of course, had to be of the single-inlet type and the area of inlet large enough to pass the required volume of air with the pressure governing the tip speed, and in turn limiting the revolutions per minute of the turbine.

One other great difficulty encountered in the early days was the true determination of the performance of the fan. With the exception of Captain Taylor's experiments and apparatus for testing fans standardized by him, little had been done in research work to determine the performance of fans of this kind. To carry out Taylor tests was an expensive operation at best, and the figures given by the fan-makers were more or less guesswork based on the more elementary apparatus necessary for cased fans, which (as has later been found out) was in no way applicable to the determination of the performance of open-type fans.

The adoption of Terry-driven units for destroyers was about coincident with the use of fuel oil under the boilers, and the correct amount of air required for the oil fuel in torpedo-boat service had not as yet been definitely determined.

Very careful tests were laid out and conducted by Mr. Charles F. Bailey, chief engineer of Newport News Shipbuilding & Dry Dock Co., on board the first vessel to be fitted with turbine blowers (the U. S. S. T. B. D. Roe), on April 14, 1910 (Journal A. S. N. E., Vol. XXII, No. 2, May, 1910). On this test two fans delivered 44,000 cubic feet of air per minute to one boiler room, at an average speed of 1,361 revolutions per minute and 3.25 inches static pressure in the fire-room. The fuel oil used per hour, 2,400 pounds; total water evaporated, 102,700 pounds per hour.

Since that time the capacity and air pressure have gone up with the increased horse-power of the new destroyers, so now the standard for destroyers Nos. 69 to 74 is 32,000 cubic feet per minute against 6 inches air pressure. This has been obtained without increasing the diameter of ventilators, but by improvement in turbine and fan efficiency, so that the total steam of the latest design is practically the same as required on the U. S. S. Roe.

The high static pressure in the fire-room and greater capacity have increased the peripheral speed of the fan to such an extent that now the type of fan selected is in part determined not only by its efficiency but by the noise it makes, as excessive noise, of course, is a tactical disadvantage to any destroyer. Furthermore, the first destroyers were fitted with mushroom-type ventilators, whereas the latest class has the cowl type, which forms a most excellent megaphone for projecting any fire-room noise.

Again, as capacities have gone up, the weight of fan has increased, and it is now generally conceded that the increased duty on the bearings when the destroyer is in a seaway, due to the gyroscopic action of the turbine unit, makes it desirable to limit the speed of these forced-draft sets to about 1,600 revolutions per minute.

The type of fan has evolved from the original Sirocco to the cone type, and then back to the multiblade, with blades of such design as is found will result in quiet running. Whereas, originally on oil fuel for destroyer service, a ratio of 225 cubic feet per pound of oil to be evaporated, was considered to be correct, now 350 cubic feet per pound is standard.

This takes care of a greater dilution, coefficient and smokeless burning of the oil as well as leakages. Smokeless operation is one of the principal points on torpedo-boat maneuvers, and in order to accomplish this in many ships an excessive amount of air is forced into the boiler rooms, even at a sacrifice of fuel economy. Photographs of early destroyers taken on trial as compared with that of the Ericsson show a marked difference in this respect.

Little authentic information could be obtained at first from fan-builders as to the absolute and true performance of the fans, and therefore there was nothing left to do but to run comparative tests. In September, 1911, three different types of fans were tested out on a comparative basis. These tests were fully described in the Journal of the American Society of Naval Engineers, Vol. XXIV, No. 4.

As mentioned in the description of these tests, no attempt was made to determine the true performance of the fans and only comparative results were looked for. In a later number of the same journal these tests were severely criticised by Mr. Schmidt, but in the meanwhile, before the publication of Mr. Schmidt's paper, further tests had been carried out on a modified box at the Terry plant and also very careful tests were carried out on board ship. These tests were very instructive, and a brief description of the same is given in the appendix of this paper.

The turbine-driven fan has proved so eminently satisfactory in destroyer work that the reciprocating engine is no longer considered. In all there are now forty-six oil-burning destroyers with turbine driven forced-draft fans, each with four complete units. Out of this number the Terry Company have supplied thirty-eight, and to date we have only a record of two actual repairs necessary to the machines due to any defects whatever, not of course considering the wear and tear of bearings, etc. This successful application of the turbine fan to destroyers has resulted in an entire change of policy in battleship work and smaller boats, also in the mercantile marine. The motor-driven fan, so long considered the standard for battleship work, is making way for the turbine blower.

For battleship work the horizontal-turbine drive is now standard in the U. S. Navy, as replacing the motor-driven sets, because of its reliability, ease of control direct from the fire-room, and also that it is not dependent upon intermediary machinery—electric generators. Plate 74 shows such a unit connected to a double-inlet fan.

A higher efficiency can be maintained on the cased fan than on the open type, and also the double inlet can be used, thus obtaining higher speeds for corresponding static pressures as compared with the single-inlet open fan.

Capacity and total steam curves of a recent unit of this type are given in Plate 75. At a rating of 17,500 cubic feet per minute and 6 inches static pressure

the total steam consumed was 2,200 pounds per hour exhausting against 5 pounds back pressure at 1,550 revolutions per minute.

Plates 75, 76 and 77 show typical types of forced-draft fans used by the German, British, and Greek navies respectively.

PUMPS.

The reliability demonstrated by six years of actual service with destroyer fans resulted in the Navy Department widening the application of the small turbine, and in 1911 specified turbine-driven centrifugal pumps on the battleship Arkansas. A serious proposition at first presented itself here on the grounds of economy owing to the slow speed necessary for the pump and the limitations of weight and diameter of turbine wheel. However, this individual turbine efficiency is not of such prime importance as would be at first imagined, and (as will be explained later) that while the turbine itself could not at first be called an efficient machine operating under the conditions at which it does, the effect of the poor efficiency when considered in conjunction with the whole performance of the ship is of little if any importance.

For reasons that will be fully dealt with later and taken into consideration in conjunction with the reliability in service, it will be seen that the lack of unit efficiency is of minor importance This is demonstrated by the fact that the latest boats have been or are being equipped with similar apparatus.

The advantages of the turbine-driven boiler feed pump have long been well known to the marine profession, but certain difficulties in their installation presented themselves, necessitating, as it was considered, special designs to suit shipboard requirements. This, together with the satisfactory service given by any good make of reciprocating pump, resulted in rather slow progress along these lines.

However, in 1912, the Navy Department decided to run exhaustive tests on a unit specially designed for their work (Plate 78). The turbine was built by the Terry Steam Turbine Co., and the pump by the Worthington Company, and tests were conducted on this apparatus at Annapolis and reported in the November, 1912, issue of the Journal of the A. S. Naval Engineers. Some interesting extracts from the official report of these tests are given below:—

"The fact that a turbine-driven centrifugal pump can be quickly started from a cold condition and put into service constitutes one of its advantages (p. 1226).

"Pumping warm water there is little difference between the economy of this centrifugal pump and the simplex pump. For cold water up to 33 per cent of full load the simplex pump is more efficient. As the values quoted are based upon a careful regulation of the number of nozzles in use according to load, the comparison will be less favorable to the centrifugal pump at light loads if such regulation is not carried out. On the other hand, the test of the simplex pump was con-

ducted under the most favorable circumstances as to the condition of the working parts of the simplex pump.

"Reciprocating pumps decrease steadily in efficiency due to wear, while the centrifugal pump will probably change very little in this respect. Further, the centrifugal pump being of the experimental type, certain slight mechanical changes will doubtless improve its efficiency" (pp. 1227, 1228).

The results of the tests carried out at Annapolis are shown in curves, Plate 80, compared with various tests on reciprocating types of pumps. These curves show up more favorably for the turbine-driven unit than would be inferred from the quotations in the report.

That the tests were satisfactory, however, is demonstrated by the fact that turbine-driven boiler-feed pumps are now being built for installation, as follows:—

One of the main advantages of the centrifugal boiler feed pumps is that they deliver a uniform pressure and volume at a given speed, eliminating entirely the vibration in the unit and piping caused by shock in reciprocating pumps. Furthermore, the pressure being kept constant, a much lower margin of pressure difference between the pump pressure and boiler pressure is obtained than with reciprocating pumps.

The ease with which a small turbine can be started up and the absence of danger due to water hammer have opened up a large field for the small turbine for ballast pumps on board passenger vessels. The necessity for making ship quickly on this type of boat is of the utmost importance. The ballast pumps on board the Hendrick Hudson were guaranteed to start from rest and be under full load in 30 seconds. Actual tests showed that this duty could be accomplished inside of 20 seconds without danger to any part of the machine or piping.

For boiler-feed pump purposes the advantage of regulating the operation of the pump by the pressure at the discharge has obvious advantages. The majority of pumps installed for boiler-feed purposes in central stations now are fitted with some type of pressure regulator with the main speed governor so adjusted that it acts merely as an emergency governor. Considerable saving in steam consumption can be effected by the adoption of a pressure regulator, as will be seen by the curves shown in Plate 80 showing the effect of pressure regulation on the total water consumption. This is particularly applicable to marine work where the demand on the boilers is a constantly varying quantity during maneuvers.

In addition to the use of turbine-driven main condenser and boiler-feed pumps the small turbine is being quite generally used for driving auxiliary pumps on vessels of large power. In this class of work there is very little difference in the marine application from that of similar use on land.

Turbine-driven ash-ejector pumps have been supplied many ships by Stone of London for both merchant and war vessels, but in this country, as far as the writers know, the only turbine ash ejectors are on the older battleships and two colliers. The turbine is eminently satisfactory in this service, as steam can be turned on without warming up and full delivery head obtained almost instantly.

Turbines can also be effectively used on bilge pumps. Other applications are for auxiliary condenser, sanitary service, fire and ballast pumps. Plate 81 shows the latest design of three-bearing turbo circulating pump for destroyer work, and Plate 82 a special pumping unit for grading the banks of the Mississippi River.

DETAIL DESIGN OF SMALL TURBINES.

It is only natural to expect that small turbines as designed for land work need certain modifications to conform with marine practice. However, in the large majority of cases, as for instance where comparatively low speeds are required, practically no modifications, or at most very slight modifications, are required from standard stationary practice.

For forced-draft blower sets on board torpedo-boat destroyersc a special vertical design of machine had to be developed for this work. The first design accepted by the Bureau, and which has been standard up to a year or two ago, consisted of a three-bearing unit, a steady bearing being considered necessary at the outboard end of the fan, or, in other words, secured to the intake duct. As this steady bearing could not conveniently be made integral with the main turbine frame and had to be supported from the light steel work composing the intake duct, a certain amount of difficulty was experienced in keeping this machine in line. This difficulty, however, has not been as serious as would be at first imagined, and some builders still favor this arrangement. In order to overcome this, however, later designs have been fitted with only two bearings with a very stiff, hollow shaft eliminating the necessity for this outer bearing.

For low and moderate speeds, such as that required for pumps, horizontal blower sets, etc., standard ring oil bearings have proven perfectly satisfactory. In land practice it is considered that for ring oil bearings a PV (pressure in pounds per square inch times rubbing velocity in feet per second) of 450 or 500 is perfectly safe. In marine work, however, a considerably lower limit should be used, especially in small boats, owing to the rocking of the vessel and the uncertainty of a uniform supply of oil being delivered by the rings. It is therefore becoming universal practice to supply all such apparatus as generator sets with their own forced feed system. It is advisable to still retain the oil rings (in addition to provision for forced lubrication) for starting up and as a safeguard against accident to the oil pump.

The glands or stuffing boxes of small turbines should be of such a type as to require absolutely no lubrication, in order to eliminate any necessity for oil or grease separation in the feed-water heater. In all small turbine work the critical speed of the rotor should be well in excess of the maximum running speed. This point is of more than particular importance in marine work where units are required to run through a large variation of speed.

EFFICIENCY.

As mentioned earlier in the paper regarding the poor unit economy of such apparatus as the Arkansas circulating pump, it must be borne in mind that when operating auxiliaries non-condensing and utilizing the exhaust steam either in the feed-water heater or in the low-pressure main turbine, a big sacrifice can be made in the auxiliary efficiency without materially affecting the over-all fuel consumption of the whole ship. When a small turbine operates with an efficiency of 30 or 40 per cent you are only extracting this said 30 or 40 per cent from the steam. The consequence is, the remaining heat—namely, 70 and 60 per cent respectively—is not destroyed but can be utilized to good advantage elsewhere. Curves (Plate 84) show the heat extracted per pound of steam by an auxiliary turbine, and also show that a very big difference in steam consumption per horsepower is permissible without materially affecting the efficiency of the whole cycle.

On curve, Plate 85, is plotted the quantity of auxiliary steam used at various speeds in percentage of the total. In the curve the 100 per cent speed represents the maximum speed on trial trips.

It was interesting to note that, after plotting the curve, the percentage of auxiliary steam could be closely approximated by the following formula:—

$$A = \frac{1300 + \frac{100 - S}{0.2}}{S}$$

where A = percentage of auxiliary steam to total steam and S = percentage of maximum speed of the boat.

The following calculations will show the very small effect actually resulting in a marked improvement in the steam consumption of a piece of auxiliary apparatus. These calculations are not meant to be accepted as absolute figures, but will tend to serve the purpose intended, namely, to show that the unit of economy of the auxiliary apparatus is not of such vital importance as would be at first imagined.

It has been necessary at the outset to make certain assumptions, and the type of apparatus used in the one instance is a direct-connected low-speed turbine circulating pump, the second case being a gear-driven unit. It has also been assumed that all the steam exhausting from the turbine can be returned to work in the feed-water heater. This, of course, is subject to criticism, but, as mentioned above, the figures are not intended to be absolute but merely an indication of the difference that is to be expected between a high-efficiency and a low-efficiency unit.

One very strong point that this question brings out is the fact that it is not in the turbine itself where we must look for efficiency, but in the driven end of the apparatus. Within reasonable limits the efficiency of the turbine matters little in the over-all fuel cost, as the heat rejected can be turned to useful work, but in the driven member anything below 100 per cent efficiency must be considered as a dead loss.

	Direct connected.	*Geared.*
1. Horse-power	347	340
2. Efficiency ratio	0.25	.47
3. R. P. M.	1350	3620
4. Ideal water rate (250 — 10 lbs.)	14.55	14.55
5. Actual water rate (lbs. per B. H. P. hr.)	58.2	31
6. Total steam per hr. = (1) × (5)	20195.4	10540
7. Total heat per lb. at 250 lbs. pressure	1199.2	1199.2
8. Heat in exhaust with 100% efficiency	1024.4	1024.4
9. Available heat = (7) — (8)	174.8	174.8
10. Actual heat used = (9) × (2)	43.700	82.156
11. Heat required per lb. to be generated to run circulating pumps = (7) — (Head of liquid of exhaust)	991.2	991.2
12. Total heat requisite to run circulating pumps = (6) × (11)	20017680.48	10447248.0
13. Total heat returned to system per lb. steam = (7) — (10) + 208.6	946.9	908.444
14. Total heat returned to heater = (6) × (13)	19123024.26	9575590.0
15. Total heat chargeable to circulating pumps = (12) — (14)	894656.22	871658.0
16. Same as (15) for two turbines = (15) × 2	1789312.44	1743316.0
17. Total steam required for remaining apparatus (lbs. per hr.)	600000	600000
18. Total heat required for remaining apparatus = (17) × (7) — 70	677520000.0	677520000.0
19. Saving by using gears (16 Col. 1) — (16 Col. 2)	.....	45996.44
20. Total heat for all purposes = (18) + (16)	679309312.44	679263316.0
21. Per cent saving = $\frac{(19) \times 100}{(20 \text{ Col. } 1)}$	.....	.00677

To improve the unit efficiency of various parts of the apparatus, gears are being resorted to.

Regarding the advantage of gear-driven auxiliaries, it is true the unit efficiency is improved, and granted that remarkable developments have been made in recent years towards the production of a satisfactory gear, it is nevertheless a fact that the gear-box considered as a unit is another piece of apparatus to take care of, and the writers' experience has been that this piece of apparatus is still far from perfect. Of course there are good gears, but the successful operation apparently depends so much on perfect workmanship that there seems to exist a big element of

chance as to whether a gear will or will not be satisfactory, or, if initially satisfactory, will stay so.

The noise created by an imperfect gear in the confined spaces on board ship must necessarily be more disagreeable than in a large power-house, and the above, taken into consideration with the really small saving in the over-all economy as pointed out later, leaves the writers very skeptical as to the net advantages.

Two of the sister battleships now building, the Idaho and the Mississippi, are equipped with direct-connected and geared circulating pumps respectively, and some very interesting comparative results should be forthcoming. Also the comparative cost of upkeep after twelve months of operation will undoubtedly throw very valuable light on this subject.

Another innovation was made by Mr. Wetherbee, of the Bath Iron Works, to reduce the unit steam consumption on the blower turbines, viz., by arranging the turbine blowers so that they could be operated either singly or in parallel. For running at full speed the blowers are operated as single units, and at cruising speed they are operated in series. A very marked improvement in economy has resulted from this combination.

One point it might be well to bring out here when considering the question of efficiency, and that is the ease at which the total steam passed by a turbine auxiliary can be quickly and accurately measured without the aid of any measuring tanks, etc., and it appears to us that this should be extremely useful on trial trip work.

Practically all small turbines expand the steam in the initial jets to a point below the critical velocity, so that Napier's formula for the flow of steam through jets will give results as accurate and probably more so than any weighing or measuring method. All that is necessary is an accurate gauge placed right in the steam ring and a record taken of the dimensions of the throats of the jets. It will be found that all makers of small turbines are very particular about the design, shape and dimensions of the jets being made to accurate plug gauges so that the dimensions of the jets can be relied upon with certainty. Napier's formula reads:—

$$W = \frac{PA}{70}$$

where W = weight of steam per second.

P = absolute pressure before the jets in pounds per square inch.

A = the area of the jets in square inches.

From actual experience it has been found that for the majority of small turbine work and the small jets that are necessary for the expansion of high-pressure steam, a coefficient of 72 is more accurate than 70, and this in turn simplifies the formula given for the flow of steam per hour as follows:—

$$W_1 = 50PA$$

where W_1 in this case equals the pounds of steam per hour.

SUPERHEAT.

The increasing use of superheat in power-houses has to a large extent been responsible for the growing popularity of the small turbine for auxiliary drive with the attendant elimination of internal lubrication, etc., and the same advantages in favor of the turbine naturally present themselves in marine work with the ever-increasing operating temperature.

A particularly interesting investigation was made some time ago by Captain Clarence A. Carr on "American Practice in Using Superheated Steam" (see Journal), and the advantages of the turbine-driven auxiliary under high temperatures were repeatedly advocated by the different authorities quoted.

CONCLUSION.

In conclusion we would like to bring out the point that the successful application of the small turbine for marine work is due in a large extent to the cooperation and suggestions made by the Navy Department and marine engineers of long experience, and their cooperation and their lack of prejudice against anything new, so often experienced in land work, have made the present situation possible.

The Navy Department has always listened to any suggestions regarding modifications of specifications which experience has found desirable in this class of work. The marine engineers and naval architects of the different shipyards have also added very materially to the development of this field by their valuable suggestions from time to time, and it is to these gentlemen we wish to extend our thanks as representatives of turbine manufacturers for the successful status of the present day of the small steam turbine in marine work.

APPENDIX.

Further tests than those referred to in the text of the paper were carried out, both by a modified box method and an actual shipboard test on the U. S. torpedo-boat destroyer Terry, to eliminate the uncertainty of the previous box-method tests.

Mr. Schmidt's criticisms of the original tests (see Journal A. S. N. E., Vol. XXV, No. 1) were quite beside the point, as these tests were purely comparative, and as clearly stated in the report of these tests no attempt was made in view of the apparatus available to determine the actual delivery of the fans.

In the test carried out on board the U. S. torpedo-boat destroyer Terry, the following method was employed. Air was measured on entering the fans, as the fire-room leakage prohibited any other means of accurately measuring the air. The inlet duct was increased to 12 feet above the normal inlet to the fan and was 41 inches in diameter. In this inlet tube a standard Taylor pitot tube was located as shown. This tube was so arranged on a slide that readings could be taken at all points across the diameter. A manometer inclined at an angle of 15° giving a ratio of .2588 to 1 was used in measuring the ingoing air.

Static pressure in the fire-room was measured by a vertical manometer of the usual type located in the fire-room, one end being connected to the outside atmosphere. Temperatures were also recorded.

The readings of the first tests were very unsteady. Adjustments made in the pitot-tube openings were without result. A slight wind varying in velocity and direction disturbed the readings. In the next test the pitot tube was secured by wire stays to prevent vibration, but no improvement was noticed.

Plate 86 shows the irregularity of the readings taken, these readings being taken by moving the pitot tube to various positions across the diameter. Averaging up the results of these tests will give a velocity of 2,279 feet per minute, air temperature of 79° F., density .073, area of inlet tube 9.17 square feet, corresponding delivery 20,900 cubic feet per minute at constant 5-inch static pressure.

Further tests were made by lowering the pitot tube to position B shown in Plate 87 (Exp. 1); also various devices were employed for preventing the tube from vibrating.

Directly adjacent to the walls of the tube the manometer would steady itself. It was therefore considered that the inductive windage over the duct of the inlet tube was interfering considerably with the accuracy of the tests.

A hood was next fitted, as shown in Plate 87 (Exp. 2), to increase air velocity, minimize wind effect and prevent eddy formation. Tabulation of the tests follows:—

	Side distance from center.	*Velocity pressure on inclined manometer.*
B	19.25	1.45
B	16	1.3
B	12	.97
B	8	1.00
B	4	.95
Center	Center	.95
A	4	.95
A	8	.95
A	12	1.1
A	16	1.35
A	19.25	1.62

Mean capacity—20,230 cubic feet per minute.

It will be noticed that readings were still unsteady, due, no doubt, to the sharp reversal over corner of intake.

Taking advantage of the calm weather at this time, further tests were run to indicate if the absence of wind velocity affected results. They resulted as follows:—

Speed	Vel. reading	Actual vel. head	Temperature	Density	Vel. coeff.	Area, sq. ft.	Velocity	C.F.M.	Actual C.F.M. coeff. .98
1900	2.2	.569	69.5	.0743	4020	9.17	3025	27750	27200
1800	1.975	.511	69.	.0744	4020	9.17	2870	26300	25800
1700	1.68	.435	68.5	.0745	4015	9.17	2645	24250	23780
1600	1.24	.321	68.	.0745	4015	9.17	2273	20840	20450
1500	.795	.206	67.5	.0746	4013	9.17	1820	16690	16350

These tests, shown in Plate 88, were a decided improvement and check very closely with those made by the box method at the Terry Co.'s works, despite the difference in inlet-tube sizes and air temperatures.

The diameter of inlet tube was next reduced, Plate 87 (Exp. 3), to further increase velocity and prevent eddy formation. These tests check up with reasonable accuracy with the results of the tests with the larger tube. Plate 86 shows the comparison obtained by the different methods and indicate that a coefficient of .759 should have been used in the original box tests in place of .98.

Checking up the results obtained by the quantity of air required for combustion, we get the following results:—

Lieut. A. T. Church, U. S. Navy, gives some figures on the theoretical amount of air required for various oils with different percentages of CO_2 (Journal A. S. N. E., 1911, p. 795). We find that the quantity of air burned by the Warrington

was 16,579 pounds of fuel per hour with 12.5 per cent CO_2. This corresponds to 20,000 cubic feet of air per minute entering each blower, so that it would appear that the figures obtained by the box method originally carried out, while intended to be purely comparative, were not so very far from being fairly accurate, and are certainly much nearer the mark than inferred by Mr. Schmidt, who figures only 12,750, which would give about 23 per cent less air than actually required to support combustion under the boilers.

EXPLANATION OF PLATES.

Plate 62.—Early Parsons' Double-Flow Turbine for Ship Lighting. About 1887.

Plate 63.—75 kw. Brown Boveri Lighting Set, Used in German and French Navies.

Plate 64.—75 kw. Escher-Weiss (Zoelly type) Lighting Set Used in German and French Marine.

Plate 65.—Mellons Pfenneiger German Naval Type of Lighting Set.

Plate 66.—375 kw. Turbo-Generator Built by C. A. Parsons & Co. for R. M. S. Mauretania.

Plate 67.—Terry Wireless Telegraph Set.

Plate 68.—10 kw. Standard Terry Marine Lighting Set.

Plate 69.—35 kw. Terry Marine Lighting Set.

Plate 70.—Type GF Condensing Turbo-Generator Set.

Plate 71.—Curtis Turbine Driving Worthington Pumps on the Fire Boat Deluge, City of Baltimore.

Plate 72.—De Laval Marine Lighting Set.

Plate 73.—Original 3-Bearing Vertical Terry Turbine, Swung Open.

Plate 74.—Horizontal Marine Forced-draft Set.

Plate 75.—Capacity and Total Steam Curves of Marine Forced Draft.

Plate 76.—Forced-draft Set used in German Navy. Brown-Boveri Blowers.

Plate 77.—Yarrow-Terry Forced-draft Set with Keith Fan.

Plate 78.—Special Vertical Turbine Boiler Feed Pump for Marine Use.

Plate 79.—Water-rate and Capacity Curves, Turbine-driven Pumping Sets.

Plate 80.—Efficiency Curves on Turbine-driven Boiler Feed Pumps.

Plate 81.—Condensing Circulating 3-Bearing Terry-Worthington Pumping Units.

Plate 82.—Terry Turbine Pumping Set Mounted on Dredge for Use in Grading Banks of the Mississippi River.

Plate 83.—New Vertical 2-Bearing Terry Forced-Draft Set. 32,000 cubic feet per minute, 6 inches pressure.

Plate 84.—Curves of Water Rates and Heat Extracted per Pound of Steam with Varying Efficient Ratios.

Plate 85.—Curves Giving per Cent of Auxiliary to Total Steam.

Plate 86.—Data of Velocity and Capacity Air Tests on U. S. S. Terry.

Plate 87.—Methods of Testing a Fan on U. S. S. Terry.

Plate 88.—Speed and Capacity Curves for same Fan Tested in Shop and Tested on Board Ship.

Plate 89.—Comparison of Centrifugal and Reciprocating Boiler Feed Pumps.

DISCUSSION.

THE PRESIDENT:—This paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship" is now open for discussion.

MR. FRANCIS B. SMITH, *Member*:—I would just like to make a few remarks about the practical end of the turbine pumping machinery. We have a number of them installed for handling water ballast, and we have found them very successful in regard to the capacity for speeds which can be attained by the machinery, but we had several accidents through the bursting of the turbine chest or cylinder. One of them was quite serious, as the engineer was permanently injured, and there were a good many opinions passed in regard to the cause of the wrecking of the machine. I went there and looked into the matter very carefully, and I was satisfied it was caused almost entirely, if not entirely, by the manner of the installation. They had a very large exhaust pipe so as to have as little back pressure as possible, and that was connected in the same exhaust line with all the other auxiliary machines on the boat. The turbine was set down in the lower engine-room at the lowest point of the exhaust, and the lines leading forward, taking in our windlasses and mooring machines, as well as our dynamos and steering engines and everything of that kind, were all set at a higher point, and naturally drained back that way. The accidents all happened within a short time after the turbine had been put in operation.

I was fully satisfied, after examining the wreck, that it was caused by the condensation in the exhaust lines being rushed back, where there was so little back pressure, into the turbine chamber, for I could see where the buckets had been driven over on the other side and had cut right into the body of the casing, so that I was very well satisfied it was the fault of the installation. Our service, outside of these wrecks, has been excellent with those installations.

MR. MARTIN L. KATZENSTEIN, *Member* (Communicated):—Of the various purposes for the application of steam turbines for auxiliary purposes on shipboard, I would discuss briefly some of the points brought up under the topic of turbine-driven pumps as compared with reciprocating types.

On pages 158 and 159 the authors refer to certain tests conducted at the Naval Academy to bring out the relative advantages of these types. On page 161 the statement appears that "within reasonable limits the efficiency of the turbine matters little in the overall fuel cost as the heat rejected can be turned to useful work, but in the driven member anything below 100 per cent must be considered as a dead loss." This same statement applies to any machine that is wasteful of steam. These statements require a little further explanation. Since the small turbines on shipboard must be used for driving something, their efficiency must necessarily be considered in combination with generator, fan, or pump. The efficiency of such turbines alone is not of prime importance, except as an engineering development. All rotary or centrifugal types, by virtue of their design, are inefficient. A low water rate per brake horse-power should not be considered alone. The overall duty in million foot-pounds of work delivered per thousand pounds of dry steam supplied should be the basis of comparison between the steam turbine-driven feed-pump and the direct-acting type. In this connection I

might say that figures which I have show interesting comparisons between the turbine-driven centrifugal boiler feed-pump and the direct-acting types, these of equal capacity. They show that, when correctly proportioned, the direct-acting pump is not only more economical but is financially the better investment. When the capacity grows excessive, however, the advantage of the centrifugal type becomes apparent. Two hundred and fifty thousand pounds of feed water per hour is as large a capacity as has been required in one unit for shipboard use at the present time, so far as I know, and this for reasons of fuel economy, due to the necessity of dividing the total feed water capacity between two or three units. I make these statements of these two types of pumps not in criticism of the steam turbine-driven set, as it has its proper place, but protest against the indiscriminate use of turbine-driven boiler feed-pumps where they have no place. Some steamship owners can testify to the poor results obtained by putting turbine-driven boiler feed-pumps in places where they do not belong.

The statement concerning the tests at Annapolis, referred to in the sentence at top of page 169, is not correct, in that the test of the simplex pump was conducted under circumstances that were decidedly unfavorable. Therefore a comparison between the performance of that pump and the turbine-driven pump is hardly correct. If comparisons are made between these two types they should be based on the performance of the centrifugal pump referred to, as compared with the tests at Annapolis on a 24-inch stroke Blake reciprocating pump. This Blake pump gave results in economy better than any of a similar type before or since tested, and showed that, despite the claim for better water rate per brake horse-power, the overall duty was in favor of the reciprocating machine.

The water hammer in piping from direct-acting pumps can be eliminated if the piping and pumps are properly proportioned.

I notice the authors refer in the paper only to turbine-driven feed pumps on U. S. naval vessels. I might add that the Oceanic Steamship Company vessels Sierra, Sonoma, Ventura, etc., as well as the Matson Navigation Company steamers and vessels of the Union Oil Company, are fitted with such pumps, those first mentioned above having been installed some years prior to their adoption by the Navy Department.

Mr. London and Mr. Herbert (Communicated) :—Mr. Francis B. Smith refers to several accidents that have taken place due to bursting of turbine shell or cylinder, but we are glad to note that the accidents mentioned were almost entirely, if not entirely, attributed to the manner of installation and not in any way due to the design or type of machine employed. It is fair to assume that had reciprocating engines been employed under similar circumstances the result would have been equally if not more serious.

Mr. Martin L. Katzenstein raised some interesting points in connection with the comparative performances of centrifugal versus reciprocating pumps. Mr. Katzenstein takes exception to our statement that "within reasonable limits the efficiency of the turbine matters little." * * * But we think that he contradicts himself later on by stating that the efficiency of such turbines alone is not of prime importance except as an engineering development. We tried to show in our diagram, Plates 79 and 80, that a big variation in water rate was permissible without materially affecting the overall efficiency. Then assuming that in some cases the reciprocating pump shows up a little better, the difference is hardly worth taking into account, especially when considered in conjunction with the many advantages of the centrifugal type as outlined in the paper.

We have analyzed our figures again to meet Mr. Katzenstein's criticism and have plotted same on Plate 89, on the basis of pounds of steam per 1,000 pounds of water, which still shows the advantages on the side of the turbine pump with hot water.

Referring to the third paragraph of Mr. Katzenstein's discussion, he states that in the sentence on top of page 169, we are not correct inasmuch as a test of the simplex pump was conducted under circumstances that were decidedly unfavorable. We would like to quote from the official report of this test published in the Journal, which reads in part as follows:—

"From 100 per cent to 133 per cent the centrifugal pump is more efficient. As the values in the last column are based upon a careful regulation of the number of nozzles in use according to the load, the comparison will be less favorable to the centrifugal pump at light loads if such regulation is not carried out. On the other hand, the test of the simplex pump was conducted under the most favorable circumstances as to the condition of working parts of the simplex pump. Reciprocating pumps decrease steadily in efficiency due to wear, while the centrifugal pump will probably change very little in this respect. Further, the centrifugal pump being of an experimental type, certain slight mechanical changes will doubtless improve its efficiency."

We regret that Mr. Katzenstein did not give us some particulars or figures of the test referred to of the Blake pump which gave such good results at Annapolis, as we are sure this would have made a very valuable contribution to the paper.

We can hardly agree with Mr. Katzenstein in his statement that the water hammer in piping from direct-acting pumps can be eliminated. It is true that under ideal conditions this is possible, but wherever we have a reciprocating motion there is naturally a strong probability of this occurring, whereas with the centrifugal type the very principle of operation eliminates the possibility of this occurring.

We are very grateful to Mr. Katzenstein for his additional information regarding the installation of turbine-driven pumps on various commercial steamers.

Mr. Katzenstein (Communicated):—The report of the test of the 24-inch stroke Blake pump was not published in the Journal for the reason that we did not wish to have our competitors learn about the test or the economy obtained thereby. This pump has a new and patented type of cut-off valve, and the results shown are very satisfactory. For further information, I would say, concerning the statement I made of the test run under unfavorable conditions, that this applied to the pump with which the authors made comparisons. This was an old Blake $10\times7\times12$ pump which was loaned by us to the Engineering Experiment Station when they started. It had been lying about the place for several years when they suddenly decided to make a test. They did not notify us, we had no one present, and the pump was not in especially good adjustment. However, when the 24-inch stroke pump was tested, we had a representative present to see that the pump was run under conditions that were the best possible with the facilities available. I will be glad to give the authors any information that they may desire in connection with this matter.

The President:—We must extend our thanks to Mr. Herbert, and to his associate, Mr. London, for their care and trouble in the preparation of this paper, and all the useful information it contains.

The next paper is No. 14, entitled, "Superheated Steam in Marine Practice," by Mr. Henry B. Oatley, Member.

Mr. Oatley presented the paper. At the conclusion of the paper, Mr. Oatley said:—"Since the paper has gone to the printers, I have received a copy of what I think is one of the most interesting papers recently presented. This was read on October 26, 1915, before the Institution of Engineers and Shipbuilders in Scotland by Mr. James Dornan, entitled, 'On Some Alternating Types of Propelling Machinery for a Steamer.' I found it a most valuable paper, and that the writer of that paper has gone into many topics which are under very wide consideration at the present time. To anyone who is interested in the possibilities of superheated steam, that paper contains much of interest.

"Plate 95 was not as complete as I would like to have had it, but some data recently received will be added and appear in the printed Transactions of the Society, which will make this list of further interest. Some owners are reluctant in making public their test results and this is to be regretted, as some very interesting data that I have cannot be given out for this reason. This morning, however, I received permission to refer to a test that has been made on a steamer operating out of New York Harbor. This is the Lehigh Valley's tug Wyoming, and officials of the company stated that the economy shown in tests is 'in excess of 15 per cent.' The Wyoming has triple expansion engines, and it will be noted that the economy obtained checks very closely with the figures given in the paper."

SUPERHEATED STEAM IN MARINE PRACTICE.

By Henry B. Oatley, Esq., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

INTRODUCTION.

1. The purpose of this paper is to invite attention, in a general way, to the position now occupied by superheated steam in marine practice, and especially to the prominent place it now has in the minds of foreign shipowners and builders.

2. Superheated steam, *per se,* will not be dwelt upon, as technical publications and society transactions during the last ten years have devoted considerable space to this phase of the subject. Brief mention later in the paper will be made of general conditions of superheating in lines other than marine practice.

3. Superheating is largely a question of degree or amount. For the purposes of this article the following divisions will be made:—

1st. Low superheat, zero to 50° F.

2d. Moderate superheat, 50° to 125° F.

3d. High superheat, 125° F. upwards.

4. *Low Degree Superheat,* perhaps being the easiest to obtain, has, in many instances, been tried and found of some advantage. A common, and in some cases unintentional, development of low superheat has been by throttling or wire-drawing. A boiler pressure of 10 pounds or more above steam chest pressure permits, by wire-drawing through the throttle, a reduction in moisture, and, if the moisture is in small amounts, slightly superheated steam may actually be obtained; however, if some distance exists between the throttle and the steam chest, radiation losses will cause a loss of a part, or all, of the superheat.

5. Low degree superheaters are generally exposed to relatively low temperature gases. In such cases a change in the gas temperature becomes a point more to be considered than where the gases are at high temperatures. The difference between the gas and the steam temperature is, of course, small and a reduction in gas temperature which might be occasioned—for example, opening the furnace door—would easily bring the gas temperature below the steam temperature. If such a condition existed, the superheater would become a condenser, *i. e.,* would give up heat to the gases. This should, of course, be guarded against. It should also be considered that, below certain temperatures, gases deposit soot in large quantities. This may be quite easily appreciated by those who have operated feed water heaters or "economizers," many being provided with tube-scraping arrangements, either manually or automatically operated, which are intended to remove accumulated soot, thus enabling the apparatus to be operated at its designed efficiency.

6. *Moderate Superheat* has, during the last twenty years, been more widely used. Superheaters developing between 50° and 125° of superheat have been constructed in a multitude of ways, and have been operated with a greater or less degree of satisfaction, but, in marine service at least, have not obtained any uniform degree of application. This is particularly true of fire-tube boilers, as compared with water-tube construction.

7. *High Degree Superheat, i. e.,* above 125° F., has, during the past ten years, been meeting with pronounced favor in merchant service, as well as in naval construction. This statement is believed to apply much more to England and continental countries than to the United States.

8. Gray, in a paper presented before the Institution of Naval Architects on April 2, 1914, gives some very interesting figures as to steam temperatures. In the tests which he describes it was found that on a triple-expansion engine having 180° of superheat in the high-pressure chest, 100° of superheat was carried through to the intermediate chest. This practically all disappeared before reaching the low-pressure chest. In another ship having quadruple engines a superheat above 210° F. was carried to the high-pressure chest. This was decreased to about 125° of superheat in the first intermediate, and to just a trace, perhaps 10° F. of superheat, in the second intermediate, the low-pressure steam being very nearly dry. This point is considered of interest as showing that for triple and quadruple engines high superheat should be used if it is desired to obtain the large economies which are given in the tests reported within the past few years.

SUPERHEATING DEVELOPMENT.

9. To say that superheating is almost as old as the use of steam, and that it was from very early times known to be extremely efficient, is probably stating a platitude. Technical literature, in many branches of engineering, has referred at length to Watt, Hirn and others, who many years ago worked assiduously to find satisfactory methods by which they could obtain and utilize this desirable quality in steam. In 1859 the late Mr. John Penn* advocated strongly the use of superheaters and pointed out the advantages to be attained. In an article appearing in the *Mechanics Magazine*† some reference is made to difficulties experienced at that early date. It was not due to lack of knowledge, but rather to lack of suitable materials and also methods for manufacturing steam containers, in these early days, which prevented the widespread adoption of superheated steam. Watt had no steel mills and high-grade steel foundries from which to obtain the necessary plates, tubes, castings, etc., with which to build satisfactory superheating apparatus. These limitations prevailed, to a great extent, till within fifteen or twenty years of the present time and, naturally, retarded the growth of the superheater

*Institution of Mechanical Engineers, 1859.
†London, April 26, 1861.

and prevented the development of apparatus which could be cheaply constructed, efficiently operated, and easily maintained at a minimum of cost.

10. Another factor, which should not be overlooked, was that engineering practice has been relatively crude in respect to the design of details which were in contact with the steam. Cylinders, liners, valves, etc., were in many instances of a quality of material which was not always entirely satisfactory even for saturated steam. These conditions led to improvement of details, not so much with the idea of adapting them to superheated steam as making them reliable under saturated steam operation. Many details, thus improved in the past twenty or twenty-five years, have been found entirely satisfactory for superheated steam. Other details have required, with the widespread use of highly superheated steam, still further improvement. It may be accepted that, at the present time in marine practice, satisfactory service can be obtained from existing designs of details when they are called upon to be in contact with superheated steam at temperatures up to 625° F.

11. The present tendency with regard to superheating is towards an increasing amount. This is true not only in marine practice, but also in locomotive and stationary engineering. It may be a matter of some surprise, to marine engineers generally, to note what is actually being accomplished with the higher degrees of superheat. The last decade has witnessed a wonderful advance in the adoption of high degrees of superheat on locomotives. About 40,000 locomotives throughout the world, of which more than 13,500 are in the United States and Canada, are to-day operating with temperatures in the steam chest above 600° F. Some roads in this country are using 700° temperature, while in France a large number of engines are operating daily and with wonderful success, at temperatures between 750° and 800° F. Stop a moment to consider what these temperatures really mean, especially in horizontal locomotive engines, as contrasted with the vertical marine engine. The cylinders in a great many of these engines range up to 28 inches and 29 inches in diameter. They are horizontal engines, and run at piston speeds considerably in excess of those used in ordinary marine practice. Many of these locomotives operate at piston speeds of 1,500 feet per minute. That these locomotives are not small engines is proven by the daily operation on several different railroads in this country of engines in both passenger and freight service which have shown above 3,000 indicated horse-power. We must not feel, therefore, that the temperatures used on locomotives are in combination with small engines, for the modern locomotive in the United States has practically the same indicated horse-power as the average cargo-boat. In stationary practice the adoption of superheat has been very rapid, and a large number of plants in the United States are now in operation using at least 150° of superheat. In marine practice during the last fifteen years, over 1,200 ships have been fitted with superheaters, all using 150° of superheat, and the majority of which are operating with practically 200° of superheat. It is not exaggeration to state that, at the present time, well over 2,000 steamers are afloat using superheated steam, the majority of which are op-

erating with what we have classed as "high superheat." In reality the adoption of superheated steam is world-wide, and is permeating nearly all branches of steam engineering. Marine engineers in the United States have recognized the advantages of superheated steam for both merchant and naval service, but the growth does not seem to have been as pronounced here as in European countries. There has probably been some good reason for the slower advance, and it would be of interest to determine the reason, or reasons, for this situation.

AIM IN SUPERHEATER DESIGN.

12. In the development of a superheating apparatus there are a number of points which should be ever present in the mind of the designer. It is believed that the following represent fundamental requirements:

1st. Efficiency.
2d. Simplicity.
3d. Accessibility.
4th. Durability.

13. *Efficiency* in design is basic. Upon this success or failure of any apparatus must be eventually determined, and without it a low-priced device is of no value. In a great many instances a high efficiency has been offset by one or more of the three points which will be discussed below. It is interesting in this connection to note:—

"For efficient superheating, the tubes should be small, or, if large, should be fitted either with cores to form a thin annulus of steam or with deflecting plates to rotate the steam and throw the heavier and colder particles against the hot tube."*

14. Another fundamental widely accepted by designers of superheaters is for a high velocity of steam past the superheating surface. Cathcart refers to this as follows:—

"Rapid relative movement of the heat-delivering and heat-receiving surfaces increases the rate of heat-transfer, because this movement keeps the temperature difference at its maximum."

15. *Simplicity* is perhaps an easy problem. All superheaters are, in a sense, simple as compared with apparatus that has moving parts. Simple construction is directly of value, in that it generally prevents excessive cost. This latter may appear either as first cost or installation cost. In either case it represents less money to be invested, and thought and study are required to make such investment a minimum.

16. *Accessibility* demands all the ingenuity that the designer possesses. An efficient and simple apparatus would be discarded were it to be so inaccessible as to prevent inspection, renewal and repairs.

*Cathcart, Journal of the American Society of Naval Engineers, August, 1915.

17. *Durability,* which is, of course, another way of saying "long life," is another basic requirement. Failure to provide this has caused the abandonment of a great number of superheater designs. The nature of the work the superheater has to do requires its parts to be subjected to varying temperature conditions, both from within and without. Action upon the material of the superheater, both from the products of combustion as well as from the steam, and, in some designs, from intermittent applications of water, has proven destructive. When we look back upon the various designs which have been brought out, it is evident that these conditions have not been fully appreciated by those who built such apparatus.

18. Superheaters are subjected to relatively high gas temperatures, and any change in the heat-transferring ability of the superheating surface will be towards a reduction in its efficiency. This in turn will mean an increase in the temperature of the metal and consequent weakening. Tubes which are subjected to internal pressure are better able to resist deformation than those subjected to external pressure. In general, it may be said that all of the widely adopted and successfully used superheaters have had one point in common, viz., that superheater pipes are subjected to internal pressure. This has appeared to be a starting point in the minds of all designers, probably from the standpoint of safety. Watkinson, in speaking of this condition, says:—

"Attempts have frequently been made to make part of the boiler-heating surface serve for superheating the steam. In boilers of the Serpollet type this is done, and for motor car purposes, where minimum weight is one of the most important factors, this arrangement may be satisfactory. But, wherever this arrangement is used, some of the tubes or some parts of the tubes are alternately wet and red hot."*

19. The modern tendency towards high degrees of superheat has, of course, meant subjecting superheating apparatus to higher gas temperatures. On first thought this would appear to aggravate destruction of the apparatus, as there are limiting temperatures above which oxidization of all usable materials would take place. Experience, however, has shown the builders how far they may go without harmful results, and progressive designers have taken full advantage of this knowledge. It is, of course, evident that, were many restrictions removed, different materials could be used and some advantages obtained thereby. Practical considerations have required compactness in the apparatus, which undoubtedly adds some cost by making it advisable to use high-priced material.

20. From information obtained it appears that a well-designed superheater, even one that is developing high degrees of superheat, has at least a life as long as that of the boiler tubes. Many instances have come to the attention of the writer where the life of some of these superheaters is above eight years, and in some cases twelve years, without repairs of any extent. It would seem not at all un-

* Institution of Naval Architects.

reasonable to expect superheater equipment to have a life practically as great as the boiler itself. If this is obtainable, many of the objections to superheating should be removed. In many cases, even if the life of the equipment were less than eight years but where fuel economies of 10 per cent and upward are obtained, there would still be considerable on the credit side of the account.

21. It would seem from the very rapid adoption of fire-tube superheaters that the designers and builders of this apparatus have definitely determined the fundamentally correct basis for proportioning and fitting this apparatus. The cut-and-try method could not give the uniformly successful results which this design has given. It would seem that this type of apparatus, which has had world-wide success in locomotives, must be credited with flexibility and a basic law that makes it efficient, through a wide range of loads. It seems quite probable to the writer that other designs are also capable of being proportioned on a scientifically correct basis, but that they have not had a sufficient amount of study put upon them, and that the lack of their general adoption is thus accounted for.

SUPERHEATER DESIGN AND CONSTRUCTION.

22. Superheaters may be broadly classified on the basis of their location as follows:

1st. Separately fired superheaters, *i.e.*, those subjected to gases coming from a source other than the furnaces of the main boilers.

2d. Waste-gas superheaters, *i.e.*, those subjected to gases on their way from the boiler to the stack.

3d. Live-gas superheaters, *i.e.*, those subjected to gases which have not left the main-boiler evaporating surface.

23. The superheaters in each of the three classes above mentioned may be, and have been, constructed on one of the two structural methods: (a) Tubular; (b) Cellular.

24. By tubular is meant a construction which requires the steam to pass through tubes for a greater part, or all, of its path during which heat is added.

25. By cellular is meant a construction which requires the steam to pass through a chamber, usually of irregular shape, and to receive heat from gas flowing through tubes which pass through the steam chamber.

26. In other words, with tubular construction steam is carried inside the tube, which is subject to bursting pressure, and with cellular construction gas is carried inside the tube, which is subject to collapsing pressure.

27. To make these structural differences more clearly understood, it may be of interest here to devote some space to illustrating and describing a number of superheater designs which have been produced and to point out some of the characteristics of these designs, as well as their advantages and limitations. Among the early designers of superheaters, particularly for marine application, tributes should be paid to Partridge (1840?), Lamb (1858), Beardmore (1859), Boden and

Clark (1860), Butler (1860), Pullen, Cresswell and Longstaff (1860). The work which these men did, although preliminary, has been of inestimable value to those who have taken up the labor in more recent times. This series of illustrations should not be considered as complete, being intended rather to illustrate the growth towards greater structural value. By structural value is meant those features which require consideration before the adoption of any apparatus. Among these points are:

1st. First cost.

2d. Installation cost.

3d. Operating cost.

4th. Maintenance cost.

28. These four could be subdivided to quite an extent, but the writer believes it hardly necessary to consider these subdivisions in this paper.

29. In the first class (separately fired superheaters), we find that Schmidt, about 1896, built a number of tubular superheaters, and Watkinson, a few years later, constructed several different superheaters of this general type. Figure 1, Plate 90, illustrates Watkinson's tubular design, regarding which, in the paper referred to, he says*:—

"For marine, locomotive, and some other purposes, where the space available is very limited and where it is undesirable to have a large mass of brickwork, the arrangement of superheater shown is preferred. The tubes are of the inverted U form, and they are expanded into an annular tube plate *P* and this tube plate is bolted to the header *H*, which is either a steel casting or a forging. The steam enters the outer compartment of the header by the pipe *S* and leaves the inner compartment of the header by the pipe *S'*. A light steel casting *C* surrounds the superheater, and the products of combustion flow across the tubes, as indicated by the long arrows. The superheater is shown as arranged for the use of oil fuel, but it can be fired with any kind of fuel burned in an ordinary furnace or in a gas producer. An economizer of the air-heater type is shown at *A* and by means of this the efficiency of the plant is appreciably increased. The outside diameter of the casing for a superheater of this type for 150,000 pounds of steam per hour is about 11 feet."

30. Separately fired superheaters have their advocates and opponents. It is not difficult with such construction to divide the superheater into parts. This makes possible an "initial" superheater with one or more "intermediate" superheaters. These intermediate superheaters may be termed "reheaters," and there are certain advantages in superheating steam between the different cylinders. On the other hand, such a construction necessitates a very much longer path for the steam, which may result in greater losses in pressure than would be the case in a single high-degree, initial superheater. Separately fired superheaters, on shipboard, re-

*Institution of Naval Architects, June 24, 1903.

quire space which can generally be otherwise used to advantage. Then, too, there are heat losses from this type of superheater, as it cannot use all the heat generated in its furnace.

31. Fig. 2, Plate 90, shows another form of separately fired tubular superheater, in general resembling a torpedo-boat boiler. This was installed in a number of ships, but the writer has been unable to find the date on which this design first appeared. It was described by Mr. A. F. White before the Institution of Naval Engineers on November 15, 1909. There can be no doubt as to this construction developing high degrees of superheat.

32. Waste-gas superheaters have appeared in a large variety of forms. Perhaps the two most commonly known in connection with fire-tube boilers are the Watkinson and the Foster. Fig. 3, Plate 91, shows a design which was used some time before it was described by Professor Watkinson in his paper previously referred to.

33. The Foster superheater, Figs. 4 and 5, Plate 91, basically resemble the Watkinson, in that it is a U-shaped pipe with separate saturated and superheated headers. It has been modified in its detail by the following:—

1st. The introduction of a core, causing the stream to flow in a thin layer between the core and the pipe.

2d. The outer surface of the pipe is provided with corrugations, for the purpose of protecting the pipe against corrosion, and affording greater heat-absorbing surface.

3d. Improvement in the means for attaching pipes to the header is provided in this design.

34. It should be noted that the introduction of the core causes two changes in the steam section in each unit. It would appear that still further improvement is possible in this respect, by making the core continuous through the length of the element.

35. Fig. 6, Plate 92, illustrates Watkinson's waste-gas superheater of tubular construction. In this design, shown as applied to a single-ended Scotch boiler, part of the gases are conveyed through the back end to a chamber containing the superheater units, and from this chamber passed to the stack.

36. Fig. 7, Plate 93, shows the Lovekin "superheater boiler," and is of the waste-gas, cellular construction. It is interesting to note some points of similarity between this and Fig. 6. Both by-pass the gases from the combustion chamber to the superheating surface, Watkinson building the superheater outside the boiler, while Lovekin builds the superheater in the form of boiler tubes which carry the gases and are surrounded by steam. Both forms of construction provide for shutting off the gases from the superheating surface, and consequently controlling the degree of superheat, if desired.

37. Live-gas superheaters were first brought out by Schmidt in 1898, and are illustrated by Fig. 8, Plate 94. This particular design is termed the "fire-tube type," as the superheater unit is introduced into the boiler tube. It is claimed that over a million and a half horse-power of marine engines are being supplied with highly

superheated steam from apparatus of this design. Considering the location of the units in this design, any desired degree of steam temperature could be obtained.

38. Watkinson, about 1903, brought out a tubular live-gas superheater shown on Fig. 9, Plate 94. This is similar in most respects to the design shown on Fig. 6, except that the gases, after leaving the superheater, pass to the combustion chamber, and from there through the boiler tubes. No provision is shown in this construction for shutting off the gases from the superheater or controlling them, but it is probable that a damper of some kind was provided.

39. Another interesting design, brought out in 1906 by Pielock, is shown in Fig. 10, Plate 94. This construction is cellular, and consists of a box surrounding a majority, or all, of the boiler tubes, for a portion of their length. Steam is admitted to, and taken out of, this box by suitably arranged pipes. The gases, flowing in the regular manner, impart heat to the steam while passing through that portion of the tube which is in the superheater chamber. It is understood that this construction was used by Pielock on locomotives for a time, but that this design has been supplanted by the Schmidt fire-tube design. In the Pielock superheater the steam loses part of its superheat in passing through the outlet pipe that is surrounded by water and saturated steam. While the heat lost by the superheated steam goes, of course, into the saturated steam, yet it prevents the full degree of superheat which the apparatus would give, being obtained in the steam pipe outside the boiler. The lack of opportunity for inspection, and the difficulty of keeping the tubes tight where they pass through the wall of the superheater chamber, appear to offer objections to this construction.

40. The Babcock & Wilcox superheater has been especially designed for, and applied to, many forms of water-tube boilers. Its construction is quite similar to the Watkinson and Foster designs shown in Figs. 3, 4 and 5, Plate 91, so far as its basic principles are concerned, and the writer assumes that it could, if desired, be applied as a waste-gas superheater to fire-tube boilers.

ENGINE CONDITIONS WITH SUPERHEATED STEAM.

41. Reference was briefly made above to the handicap under which the older engineers labored in not having suitable materials for superheater construction. They had further obstacles to overcome in not having suitable designs of various engine parts. The following are details, aside from the superheater, which require investigation if superheated steam is to be used:—

1st. Steam pipes, valves and fittings.
2d. Steam chest valves.
3d. Engine cylinders, liners, etc.
4th. Piston rings.
5th. Rod packings.
6th. Cylinder ratios.

42. *Steam Pipes,* stop valves and fittings should contain no copper or brass. Many governmental regulations also prohibit cast iron and malleable iron. The rules of the United States Steamboat Inspection Service require steel, where "pressures of more than 300 pounds and a temperature of more than 425° F." are used. This requirement is adhered to in the best practice, both here and abroad. Steam pipes and flanges should be well insulated. This is, of course, good practice whether the steam is saturated or superheated, but lack of such insulation, when an investment has been made in the superheater, is a cause of wastefulness that ought not to be tolerated. The main stop-valve should have a cast-steel body, and the valve spindle should be of steel.

43. *Steam Chest Valves on the High-Pressure Cylinder* should be of the piston type with rings, wherever the degree of superheat is sufficient to eliminate all condensation through the first cylinder. Balanced slide valves on high-pressure chests have been, in some instances, satisfactorily operated, but, as a rule, if the temperature of the steam is 500° or more, piston valves are generally recommended. For the intermediate chest of triple and quadruple engines, or the low pressure of compounds, piston valves are desirable, but well-balanced slide valves, if properly provided with grooves for oil lubrication, have been successfully used. For the low-pressure chest of triple and quadruple engines, it would appear safe to use slide valves. The steam temperature, even with high initial superheat, to which the low-pressure valves will be exposed is but little, if any, above saturated steam operation.

44. *Engine Cylinders and Liners* must be of first-class, close-grained cast iron, as hard as can be worked. Iron, as a material, for these details has been proven to be entirely suitable for high superheat. It is well known that cast iron does not lose strength,* but on the contrary the strength increases slightly when exposed to temperatures up to about 800° F. It is probable that under exceptionally high temperatures cast iron may "grow," but, within the range of temperatures to which steam chests and cylinders are subjected with superheated steam, no appreciable change will be found. If this were really a serious matter the number of superheated steam marine plants would not be increasing at the present rate. No fear need be entertained, therefore, that there will be deterioration of these parts, due to steam temperatures up to 650° or 700°. That this is borne out by facts will be indicated by the satisfactory operation of steamships and locomotives using superheat in excess of 200°, as referred to above. In these instances, steam chests, cylinder bushings and cylinders are made of cast iron. Furthermore, in American locomotives, cast iron is almost exclusively used for the steam pipes leading from the superheater headers to the steam chest. This is standard practice on railroads, and no troubles of any consequence are found. Still more remarkable is the fact that the superheater headers in practically all locomotives, where the fire-tube superheater is used, are of cast iron. A great many of these castings have been in continual service for over five years, and the percentage of failures is very small.

*See Kent, p. 383 (5th edition).

45. *Piston Rings* (cylinder packing) should be of strong, hard cast iron. There are several designs of piston packing rings on the market which are reported as giving good satisfaction on marine engines using 200° of superheat. These designs are also applicable for valve rings.

46. *Rod Packings,* for high-pressure piston and valves, as now arranged are durable and satisfactory. Trouble was hitherto experienced in obtaining the proper designs of rod-packing, but this is no longer the case. It is the author's understanding that there is a growing tendency towards the use of soft cast iron instead of white metal in these rod packings, and it is claimed to meet all the requirements. If such is the case our ideas of this detail may have to be revised.

47. *Cylinder ratios* to be suitable for use with highly superheated steam require consideration, on account of the steam characteristics. The published dimensions of English and German superheated steamships show that a lower cylinder ratio is used. This is generally accomplished by increasing the diameter of the high-pressure cylinder, the intermediate and the low-pressure diameters, on a triple job, remaining as before. In quadruple engines, the high and first intermediate-pressure cylinders are increased in diameter, while no change is made in the second intermediate and low-pressure cylinders. In converting saturated engines to the use of superheated steam, an increase in the high-pressure cylinder diameter is not always advisable, and many times not possible. In such cases, if the same indicated horse-power is to be obtained, it is necessary to increase the cut-off in the high-pressure cylinder, thus giving an increased volume of steam at cut-off, and, in effect, decreasing the cylinder ratio. If the volume at cut-off is not increased the indicated horse-power will be slightly decreased, assuming, of course, that the boiler pressure is not changed. To explain the necessity for these modifications, it will only be necessary to point out that the expansion curve of superheated steam falls a little more rapidly than saturated steam, and, to make up for this, the volume of steam at cut-off, with say 200° of superheat, should be about 10 per cent greater than the volume with saturated steam in order to get equal power. This does not mean, of course, that the same weight of steam is used per stroke after superheating. It merely means that a 10 per cent greater volume of steam, which weighs about 30 per cent less per unit of volume than saturated steam, is used. These figures will indicate that there is still a considerable margin for steam economy, although a greater volume of steam per stroke is taken.

ENGINE OPERATION WITH SUPERHEATED STEAM.

48. The operation of engines using superheated steam is but very little different from saturated steam operation. The two chief points under this topic are as follows:—

1st. Starting up.

2d. Lubrication.

49. *In starting-up,* particularly with new engines, or if new liners or rings have been applied, nearly all superheater manufacturers recommend that saturated steam be used for a short time. After the engines are well heated, the mixing-pipe valve may be partly closed and the temperature of the steam in the high-pressure chest gradually raised. When the vessel is on a run, some hours should elapse before the full degree of superheat is used. In this way the wearing surfaces will have an opportunity of taking on a smooth finish and will afterwards work without difficulty.

50. *Lubrication* is probably the most prominent point in mind when first considering the use of superheated steam. In reality this need not cause apprehension. With low degrees of superheat, it is not always necessary to use any oil internally. This may be explained by the fact that the superheat is not sufficient to carry the steam through the high-pressure cylinder without condensation. Where condensation occurs oil lubrication may not be necessary, and this is particularly true when low pressures are carried. Low superheat really does little more than eliminate part of the initial condensation. With moderate degrees of superheat opinions differ as to the necessity for the use of oil. Cases are on record where superheat of more than 100° has been successfully taken care of without internal oil lubrication. It seems probable, however, that in such cases heavy swabbing of rods was resorted to. When high degrees of superheat are considered, lubricating oil should certainly be applied internally. The quantity of oil needed to satisfactorily take care of 150 or more degrees of superheat is probably imagined as being greater than what is actually required. The average of a large number of boats using high degrees of superheat shows that very favorable results were obtained with about 0.3 gallon of oil per 1,000 horse-power per 24 hours. One case has been reported of a 2,800-horse-power ship that used but 20.5 gallons of oil on a 42-day voyage. This is just about 0.5 gallon per day, or 0.167 gallon per 1,000 horse-power per 24 hours. Gray in his paper* referred to above, speaking of the lubrication required, says:—

"On the Port Augusta, of 2,000 I. H. P., 1.5 gallons per day of cylinder oil were used at first for internal lubricating and swabbing of piston rods of both main and auxiliary engines; on the Port Lincoln and Port Macquarie, of 4,000 I. H. P., about 2 gallons per day, this being gradually reduced until now only 0.5 to 0.75 gallon is required."

51. The keynote of the lubrication question with highly superheated steam is that a regular supply rather than a large quantity of oil is required. The oil furnishes the lubrication previously afforded by the water present in the saturated steam, but it does not follow that a regular supply of oil means a large quantity of oil.

*Paper before Institution of Naval Architects.

EQUIPMENT NECESSARY FOR SUPERHEATED STEAM OPERATION.

52. Equipment to handle superheated-steam, some of which may not be considered for saturated-steam installation, is confined to the following:—

1st. Lubricating-oil pump and pipes.

2d. Filters.

3d. Pyrometers.

4th. Mixing pipes for leading saturated steam to main steam pipe and superheated steam to auxiliary steam pipe.

53. *An oil pump,* driven from some convenient part of the engine, is required to feed oil in a steady and regular manner. Inexpensive pumps are on the market, and are reported as being reliable in service. Many of them are so arranged that the oil container is not under pressure, thus permitting a renewal of the oil supply without trouble or danger. In modern practice, the oil is introduced into the steam pipe between the throttle valve and the engine. The delivery end of the oil pipe fitting extends into the steam pipe, so that the current of steam entrains the oil and it is atomized before reaching the wearing parts. This feature has been found very important.

54. *Filters* are, of course, necessary where there is any possibility of oil being taken into the boilers. A large proportion of steamers using saturated steam in condensing engines are at present equipped with filters. It is believed that in a good many ships the filtering apparatus now installed, particularly with proper attention given to cleaning, is adequate to prevent oil reaching the boilers. A number of recently built ships, using high superheat, have had two filters arranged in series, and reports from engineers on such boats indicate that oil does not get into the boilers so as to cause any damage or give trouble. No matter how good filters may be, they will not keep oil out of the boilers unless attended to. With a double filter installation, the first filter is generally inspected and cleaned about every two days while at sea. The second filter does not require attention oftener than about once a week.

55. *Pyrometers* are desirable for measuring the temperature of the steam at various points. It appears, at the present time, common practice to have one pyrometer indicating the temperature of steam at the engine stop valve, also to have other pyrometers at points nearer the superheater for indicating the temperature of the steam where it leaves the superheating apparatus. A pyrometer to register the temperature of steam in the intermediate-pressure chest is also frequently applied. Various types of pyrometers which measure these temperatures accurately are available and are reliable instruments; the electric pyrometer, especially, appears to have been developed in a satisfactory manner for marine practice. The information given by the pyrometer is important, and makes it possible to determine:—

1st. How far superheat is being carried through the engine.

2d. Whether any boiler is being properly or improperly fired.

3d. By showing a reduction in steam temperature, gives warning of an impend-

ing fall in boiler pressure; in other words, acts as a danger signal as regards pressures.

56. *A small diameter mixing pipe* is generally provided, so that saturated steam can be taken from the boiler directly to the main steam pipe leading to the engines. The use of this pipe has been criticized in some quarters on the ground that the proportion of steam flowing through the pipe, if adjusted for a certain condition of maximum load, will, at other loads, permit a different quantity of steam to flow through the pipe, and the temperature of the engines will fluctuate. It is further contended that at light loads too much steam will pass through the mixing pipe, having a tendency to short circuit the superheater, in which case the superheater pipes may become overheated. Consideration should be given to these objections. The mixing pipe, if it can be properly applied, is of value and should not be condemned without careful study of its advantages. Probably its greatest use is that it permits of tempering the superheated steam at the engine within very narrow limits.

57. *Auxiliary Machinery* may be more economically operated when superheated steam is available. Pipes for accomplishing this may be arranged so that the desired amount of superheated steam can be led to the auxiliary steam line, the quantity depending on the kind of machines to be operated, the distance of these machines from the mixing pipe, and the severity of weather. If auxiliary machinery is fitted for the full degree of superheat obtainable, maximum economies are, of course, possible. If the machines are not arranged for superheated steam, there is still opportunity of effecting considerable saving by feeding enough high-temperature steam into the auxiliary line, to carry practically dry or even slightly superheated steam up to the auxiliary engines. With long pipe lines leading, for instance, to steam winches operating in cold winter weather, the economy in steam which is obtainable will be very readily appreciated. Winches thus provided will use steam instead of a very high proportion of hot water. In fact, the percentage of economy, by using thoroughly dry steam, in auxiliary machinery will be greater than obtained on the main engines. In converting existing vessels to use superheated steam, it is probable that the auxiliaries will not be capable of operating with more than a low superheat. New ships now being turned out are, in many cases, being provided with auxiliary machinery capable of operating with a considerable superheat.

TURBINES USING SUPERHEATED STEAM.

58. The combination of turbine engines and highly superheated steam should meet with much more favorable reception than has been accorded, until recently, to highly superheated steam in reciprocators. This may be attributed to the fact that internal lubrication, piston rings, valve rings, rod packings, filters, etc., do not require consideration, due, of course, to the character of the prime mover. It is understood that a large percentage of the turbine ships now under construction abroad are equipped for superheated steam. To the writer's knowledge, there are

now building in England eight geared turbine ships ranging from 3,600 to 10,000 shaft horse-power (averaging about 5,500), which are to be equipped with superheaters. It is probable that the degree of superheat used will be from 125° upward. Geared turbine installations with superheated steam are receiving considerable attention in the United States. There are a number of specifications now out which provide for this combination. It is probably true that some designs of turbine may not be able to use as high a degree of superheat as others, due to conditions of design and construction. Thousands of horse-power of turbines in shore installations are operating with moderate and high degrees of superheat, without any trouble.

DIFFICULTIES TO BE OVERCOME.

59. Difficulties have existed chiefly as regards:—

1st. Lubrication.

2d. Filtering.

3d. Superheater design.

4th. Superheater maintenance and repairs.

5th. Engine performance.

60. That these difficulties have been overcome is evidenced by the increasing interest in superheaters by shipowners and builders. These points have been dwelt upon quite fully in the preceding paragraphs of this paper.

61. With the wider use of turbines as mentioned elsewhere in this paper, the use of superheated steam will receive added impetus. This may be taken as an indication that the superheating apparatus has been developed to a commercially attractive standpoint.

62. There can be no question but what the earlier difficulties encountered with superheated steam have remained vividly in the minds of a great many marine engineers and some shipowners. It should not, however, be accepted that these difficulties necessarily exist today; at least the progressive engineer should inquire as to whether it is now possible for him to make use of highly superheated steam satisfactorily and avoid, without radical change in design, the troubles which were earlier experienced. Marine engineers, like those in other branches of engineering, are not in all cases inclined to take this point of view. Some find it easier to dismiss the subject with the thought that insurmountable difficulties are bound to come up and that it is easier "to let the other fellows do the experimenting." Such a position in this matter is that "any economy will be to the owner's benefit, but any trouble from the apparatus will be to the engineer's discredit." The attitude thus expressed is greatly to be regretted, as it indicates that such a one is inclined to believe that progress has reached its highest point, and that from now on we can expect little in the line of added efficiency and economy. The writer believes, however, that men holding this point of view are less frequently met with than formerly, and that the superintending engineer of today is becoming very open-minded in problems which mean for advance in marine engineering.

ADVANTAGES TO BE GAINED BY USING SUPERHEATED STEAM.

63. What will be the advantage, and what has the shipowner to find of interest and value, by installing superheaters? Briefly they appear to be:—

1st. Fuel economy.

2d. Water economy.

3d. Reduced valve leakage.

4th. Increased boiler capacity.

5th. Increased revenue cargo space.

64. *Fuel economy* cannot be any less important in the future than it is to-day. If any change in fuel costs takes place, they will go up rather than down, and, as they increase, the question of fuel saving will become more pressing. With the use of reciprocating engines, superheating presents practically the only source of further pronounced economies that is left to the engine designer.

65. Plate 95 shows, in tabular form, all of the tests which the writer has been able to find. We hear railroad men talking eloquently and continually of fuel economies of 25 per cent, 30 per cent, and in some cases 35 per cent. To expect these in marine practice is, of course, out of the question. The marine engine as it stands to-day is a much more efficient and economical plant than the railway man has had available. Superheating, therefore, has permitted a higher percentage of economy on the railways than is possible in marine practice. It may, however, be concluded that, assuming 150° of superheat at the high-pressure chest, the following fuel economies may be confidently expected in average practice:—

Compound engines, 18 per cent.

Triple expansion engines, 15 per cent.

Quadruple expansion engines, 8 per cent.

66. Many of the tests shown on Plate 95 are in excess of the figures just quoted. In well-designed and well-built plants operating efficiently with saturated steam, these large economies may not always be obtained.

67. *Water economy* is obtained wherever we get fuel economy. In percentage, the economy in steam will be greater than in fuel. An 8 per cent fuel economy by superheating gives 10 per cent and upward of steam economy. It will be readily appreciated that an economy of steam of this amount is directly of advantage in reducing:—

1st. Boiler maintenance, as the quantity of water to be evaporated is decreased.

2d. Work demanded of the evaporators.

3d. Work required of feed water pumps and condensers.

68. These, directly and indirectly, are advantages that should be taken into account.

69. *Leakage past piston and valve rings* is a great source of loss. It has been demonstrated that water leaks more readily than steam, and that the heat loss is greater. This accounts, in part, for a greater water than fuel economy in using superheated steam. Professor Perry says:—

"It is to be remembered that it is the existence of water round the piston and valves that enables leakage to be fifty times as great as if there was no water."

70. Callendar and Nicholson, in describing their well-known experiments, say that "hot water leaks through a crack and past valves and piston with far greater facility than does steam."

71. *Boiler capacity* as an asset is real, but rather difficult to express in figures. This may, in the minds of some, not be of particular moment. What is meant by boiler capacity in this sense is that, assuming a given power with saturated steam and we applied a superheater, the same indicated horse-power is obtainable with, say, 8 per cent less fuel and 10 per cent less steam. If, for any reason, it was desired to force the boilers and engines, and to burn the same amount of fuel as with the saturated steam, the output measured by engine horse-power will be increased more than 10 per cent. Of course all ships may not have engines capable of developing this increased output on demand, but a great many do. For ships which have boilers relatively small in comparison with the engines, there appear to be great possibilities in fitting them with superheaters.

72. *Greater revenue cargo* is obtained by virtue of the fact that decreased tonnage of bunker coal is required for a given voyage. The saving in dead cargo can be converted to paying cargo. The added income from this source should be considered in connection with the possible use of superheated steam.

SUMMARY AND OUTLOOK FOR SUPERHEATED STEAM.

73. It is the writer's opinion that the situation, as regards superheaters and the use of highly superheated steam, may be summed up by stating that designs suitable from the standpoint of efficiency, simplicity, accessibility and durability are available for shipowners. Also that the difficulties which discouraged the earlier designers have been overcome as regards detail designs and operating conditions, and, therefore, the installation, operation and maintenance of high-degree superheaters appears to be not only possible, but practical and beneficial. Gray, in his paper several times previously mentioned, states the following:—

"The number of steamers fitted with superheaters during recent years is an indication of successful working under superheat conditions. The following figures, though far from being a complete record, are worthy of note and consideration:—

	No. of steamers		*Total I. H. P.*
Schmidt's superheaters	1,042	Cylindrical boilers	1,322,092
Hide	20	Cylindrical boilers	.....
Yarrow	13	Water tube boilers	261,000
Babcock & Wilcox superheaters..	29	Water tube boilers	316,675
Thornycroft superheaters	....	Water tube boilers	60,000

74. In this it will be noted that he credits the Schmidt superheater as being applied to slightly over 1,000 vessels, but recent information show over 1,200 steamers at present equipped, and that they total approximately 1,800,000 horse-power. Furthermore, the Foster superheater has been, according to information received, applied to 6 ships which have an aggregate of about 16,000 horse-power. It is believed that the figures given above, when supplemented by other installations, will give a total of over 1,500 ships using superheated steam, aggregating indicated horse-power of 2,300,000.

75. Is it then too much to expect that the American merchant marine will, in the next few years, very actively take up the question of superheating steam? And is it not reasonable to expect that a few years will find us comparatively abreast of English and continental shipbuilders in regard to this very important means of reducing operating expenses.

76. In closing, the writer wishes to make acknowledgment to Prof. W. H. Watkinson's and Mr. Harry Gray's papers before the Institution of Naval Architects, dealing with this general subject.

77. Attached, as an appendix, is a bibliography of articles relating to marine superheaters and closely allied topics which will be of reference interest.

APPENDIX A.

PART I (AUTHORS).

BRAUSER, P.

The Design of Recent Superheaters for Marine Boilers (Berechnung Neurer auch für Schiffskessel Verwendbarer Ueberhitzer). Die Turbine, June 5, 1908.

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APPENDIX B.

Part II (Publications).

American Society of Naval Engineers, Journal of:—

Vol. I, page 152,	Superheaters, Value of.
III, page 588,	Superheaters, Practical Use of.
III, page 588,	Superheated Steam and the Serpollet Boiler.
VIII, page 130,	Errors in Measuring Temperatures.
VIII, pages 346, 351,	Steam, Various Types of Superheaters and notes on.
VIII, page 346,	Notes on Superheating.
X, page 205,	Economy by Superheat.
XI, pages 486, 1073,	Superheated Steam.
XII, page 749,	Receiver Superheating, Efficiency of.
XIV, page 280,	Superheaters, Value of.
XIV, page 539,	Experiences and Results.
XVI, page 328,	Advantages of Superheating.
XVII, page 834,	Test of Superheated and Saturated Steam, Steamer J. C. Wallace.
XVII, page 498,	Hering Superheater.
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XVII, page 493,	Schwoerer Superheater.
XVII, page 500,	Uhler Superheater.
XVII, page 487,	Recent Progress in Their Construction.
XVIII, page 287,	Experiments with Superheated Steam.
XVIII, page 617,	Specific Heat of.
XIX, page 1072,	Superheated Steam, Material for the Control of.
XX, page 1,	Superheating of Steam (Translation), Benj. F. Isherwood.
XXI, page 771,	Superheating, Bauer Modern Turbine Installation.
XXI, page 1374,	Superheat, Cast Iron with.
XXI, page 1375,	Lubrication of Steam Cylinder with Superheat.
XXI, page 1039,	Test of Pumping Engines with and without Superheat.
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XXII, page 543,	Superheating.
XXIV, page 644,	Superheaters in Marine Boilers.

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1860, Vol. I, pages 177–182, Superheating.
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1867, VIII, page 159, Superheaters, when Advantageous.
1882, XXIII, page 49, Superheated Steam, Difficulties in Use of.
1882, XXIII, page 44, Superheated Steam, Example of Economy Due to.
1892, XXXIII, page 66, Superheaters, Introduction of in Navy.
1897, XXXVIII, page 240, Superheaters Used in the Turbina.

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1904, Vol. IX, page 216, The Central Superheater.
1904, IX, page 170, Use of Superheated Steam.
1904, IX, page 247, Use of Superheated Steam.
page 236, Superheated Steam, Editorial on.
1907, XII, page 371, Pielock Superheater on S. S. La France.
1909, XIV, Superheated Steam in Marine Work.
1909, XIV, page 249, Superheated Steam in Marine Work.
1909, XIV, page 290, Superheated Steam in Marine Work.
1909, XIV, page 384, Superheated Steam in Marine Work.
1909, XIV, page 280, Superheated Steam, Editorial on.

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1915, January, page 8, Superheated Steam.

Northeast Coast Institution of Engineers and Shipbuilders:—

1900-01, Vol. XVII, page 112, Discussion on G. M. Brown's Paper.
1910-11, XXVII, page 111, Discussion on Schmidt Superheater.
1912-13, XXIX, page 32, Presidential Address.
1913-14, XXX, page 29, Presidential Address.
1913-14, XXX, pages 424, 425, Bibliography of Papers Published During the Last 15 Years.
1913-14, XXX, page 426, Discussion by Sir C. A. Parsons, A Review of the Progress of the Marine Steam Engine on the Northeast Coast During the Last 15 Years.
1913-14, XXX, page 430, Mr. Portham's Discussion of Same Paper.

Pacific Marine Review:—

1915, Vol. XII, page 58, Superheated Steam and the Merchant Marine.

DISCUSSION.

THE PRESIDENT:—Discussion is now in order on this paper, entitled "Superheated Steam in Marine Practice," by Mr. Oatley. I understand that Mr. E. H. Peabody, Member of the Society, has a written discussion by Mr. Walter M. McFarland that he wishes to present.

MR. WALTER M. MCFARLAND, *Vice-President* (Communicated):—I have read Mr. Oatley's paper with much pleasure, and desire to thank him for the pleasant references to the work done in superheating by my company, The Babcock & Wilcox Company. The table on Plate 95 would appear to show that the first published results in almost forty years were based on the performance of Babcock & Wilcox boilers and superheaters.

This, however, is not quite correct, and it leads me to express regret that in paragraph 9 on page 174, where Mr. Oatley gives the names of some of the leaders in marine engineering who have experimented with superheaters, he omits one who certainly did as much as any of those men, and who in a paper before an American society should not be omitted. I mean, of course, our great engineer Isherwood, who passed away only this last summer.

In his famous work entitled "Experimental Researches in Steam Engineering," and published in two volumes in 1863 and 1865, there are records of at least five elaborate tests of superheating, which were conducted with his usual care and extent. By the latter I mean that the individual tests lasted for seventy-two hours each. In the case of the steamer Eutaw, tested at the Washington Navy Yard in 1863, there were fifteen of these separate tests at different points of cut-off, using saturated steam and superheated steam, and the test at each point of cut-off and each condition of steam lasted seventy-two hours.

It may be of interest to note here that the Eutaw had separately fired superheaters, so that it was possible to vary the degree of superheat with other conditions remaining the same. In these tests, where the steam pressure was about 26 pounds, with the temperature for saturated steam about 270° F., the superheat varied in the different experiments from 87° F. to 125° F. The maximum economy shown in the experiments as due to superheating was about 23 per cent of the saturated steam per horse-power.

It may be of interest also to record here that the famous steamer Wampanoag, and her equally successful sister, though not so well known, the Ammonoosuc, were equipped with superheating boilers. This is clearly shown in the cut opposite page 566 of Bennett's "Steam Navy of the United States." These vessels were tried in 1868, during Isherwood's last year as engineer-in-chief of the navy. I mention these last to show that Isherwood's earlier experiments had so well satisfied him of the value of superheat that, in the greatest successes of his official career as engineer-in-chief, he continued to use it.

The query naturally arises why superheat should have been so abandoned for more than thirty years, when the knowledge of its benefits was so well known. I cannot agree entirely with Mr Oatley that this was due to the inferiority in materials and workmanship as compared with existing conditions, although present conditions are, of course, a decided improvement. It seems to me that the reason is right at hand when we remember that just about this time (1865-1870) the compound engine began to be used extensively, with the accompanying great increase in fuel economy. As just stated, the experiments on the Eutaw

had shown an economy of nearly 25 per cent, but the earlier economies with the compound engine were fully as much as this, if not more.

As soon as the compound engine had shown its superiority with steam of moderate pressures (say, 60 to 70 pounds), pressures were gradually increased until compound engines were working with pressures as high as 120 pounds. Then came the triple expansion engine, with a further decided gain in economy, and with gradually increasing pressure. When steam pressures had risen to about the limit for cylindrical boilers, it was natural that designing engineers who sought for greater economy should remember superheat, and begin to experiment with it again.

I am sure that we all feel indebted to Mr. Oatley for the practical discussion of the question which he has given, and we must remember that he distinctly disavows at the beginning of his paper any intention of discussing superheat itself, but is rather concerned with its practical application.

Mr. Luther D. Lovekin, *Member:*—Mr. President and members of the Society of Naval Architects and Marine Engineers, I have read the paper presented by Mr. Henry D. Oatley, entitled "Superheated Steam in Marine Practice," and congratulate Mr. Oatley on his timely, important and interesting paper on this subject.

It was quite a surprise to me to learn that from twelve hundred to fifteen hundred ships have been equipped with superheaters. I was fully cognizant of the great work done in this country with the Schmidt superheater on locomotives. In fact, I had the pleasure of discussing this subject with Mr. J. T. Wallis, General Superintendent of Motor Power of the Pennsylvania Railroad, at Altoona, Pennsylvania, a short time ago, and Mr. Wallis showed me at that time the daily records of locomotives equipped with and without superheaters on regular runs between New York and Philadelphia. The actual savings in coal averaged more than 30 per cent.

Mr. C. D. Young, Test Engineer of the Pennsylvania Railroad, delivered a most interesting lecture on the subject of superheating before the Franklin Institute recently, in which he gave the actual results of probably the most exhaustive tests ever conducted on the Schmidt superheater, and to anyone who may be at all interested in the subject of superheating a reference to this work would be invaluable. I personally know that as a result of these tests a piston valve which was formerly 15 inches in diameter, "before superheaters were being used," has since been cut to 12 inches in diameter for the same amount of work. The reduction in the piston valve enabled the valve gear to be reduced in weight, and consequently the inertia forces have been greatly reduced, which is also an item of great importance in locomotive work.

I notice the author questions the railroad men talking eloquently and continually of fuel economies of 25 to 35 per cent, but when we consider the great value that the Schmidt superheater has shown for locomotives in actual service, and know from actual experience that results of 30 per cent, and more, have actually been obtained, we can readily understand why the railroad men are so enthusiastic. As Mr. Oatley justly remarks, to expect this in marine practice is, of course, out of the question. Personally I am inclined to believe that we have as yet a great deal to learn as to just what the real difference in economy is between marine engines fitted with superheaters and without superheaters, for the reason that very few tests have been made on a vessel having the same machinery with and without superheaters.

In order to ascertain as far as possible the actual saving due to superheat on a moderate scale, we are building at the New York Shipbuilding Company's works, Camden, New Jersey, a collier which is being equipped with two Scotch boilers fitted with my superheating arrangement, which, however, is not in accordance with the author's illustration in the preliminary paper of my superheater, but is in accordance with Plate 93. It is our intention to run a series of tests with the superheater in use, recording all the necessary data, and then to run a series of tests without the superheater in use and record the same data. This will enable us to form an exact comparison that will be indisputable on account of the conditions being the same. In my early type of superheater, as shown by Mr. Oatley, the superheater tubes in the upper part of the boiler were in free connection with the steam space in the upper part of the boiler, and, realizing that this would not prove effective, I designed the superheater referred to previously, and, as shown on my latest plan, in order to overcome this possible defect. It will be noticed that my last form of superheater utilizes the two outer rows of tubes as drying tubes, in order to absorb any moisture that might exist in the steam prior to entering the superheater tubes proper. Any moisture that has collected in the drying tube chamber finds its way through a pipe down to the water spaces below, and the dry steam then passes over the superheating tubes in counter current to the flow of the gases over and under the baffles shown in the central group of tubes only.

I have not attempted to obtain a high degree of superheat on the boilers we are building, and it has been a very difficult matter to interest the average engineer in any degree of superheat up to the present time, and, while I strongly favor a high degree of superheat, I have designed the present boilers with a view to giving absolutely dry or a slight degree of superheat, not more than 50°. I have endeavored to make the apparatus as nearly foolproof as it possibly could be, and therefore have made the tubes from the combustion chamber into the uptake about the same size as the stay bolts. They have holes of ⅞ inch in diameter, in order to reduce the temperature of the gases from about 2,500 down to 1,000°, with the damper full open. It would have been possible to have kept the same sized tubes in the back of the combustion chamber as the regular tubes and then to have operated the damper when regulating the temperature of the gases, but, of course, there would have been the possibility of having the damper open too far and therefore the temperature too high. In the upper part of the boiler I have used tubes of ¼ inch thickness and expanded the ends into recesses in the heads of ¼ inch wide by 1/16 inch deep and beaded the same over at the ends, thus forming a very good head stay. I had also considered using spirally corrugated steel tubes for this purpose, together with the usual head stays, in order to avoid any adverse comment in regard to the possible trouble due to the difference in expansion between these tubes and the shell, but, after considering the expansion and contraction of the regular tubes in all boilers, I felt convinced that the work on the tubes of my superheater would be no more severe than is encountered in every-day practice with said regular boiler tubes.

Mr. Ernest H. B. Anderson, *Member:*—Mr. Chairman and gentlemen, it has not been generally recognized in this country that the regular impulse reaction Parsons turbine is suitable for superheat. The impression has been that the drum construction of turbine does not permit of the use of a very high superheat. This is not so, provided that the turbine is designed to use superheated steam. The reason it has not been adopted more than it has in marine work has been largely due to the superheaters. One never knew whether the degree of superheat would be limited—it might be 100 degrees or it might be 200 degrees, and that

has influenced marine engineers with regard to the adoption of superheat. If you use superheated steam with high-pressure turbines, the part of casing which is subjected to the high temperature steam requires to be made of cast steel, and it has been very difficult to obtain sound castings from the foundries. I must say, however, that they are now turning out very much better work in this respect. The blading, too, has to be of special material, and by making this of copper, superheat can be used with complete success in marine work as it has in the past with land installations. As the author says, I think superheated steam is going to be used in marine turbines very largely in the future.

Mr. E. H. Peabody, *Member*:—I would like to say a few words in this discussion on my own behalf. I think that this Society is greatly indebted to Mr. Oatley for again bringing before it the importance of, and particularly the great increase in the use of, superheated steam. There has been too much of a tendency, I think, in this country, to attribute troubles to the superheaters which really should never have been attributed to them, and not enough effort has been made to overcome some slight troubles which were due to superheaters.

I remember that the first superheater I had any experience with was in connection with a stationary plant and Corliss engine, and after some weeks of experimentation the superheater was thrown out, because the engine would not take care of the superheat. In that case, doubtless, the situation was exaggerated, and the superheater was much less expensive than the engine. I only mention the incident as showing the tendency which we have sometimes had in regard to superheaters. We do not work sufficiently hard to obtain the undoubted advantages of superheat, although, as Mr. Oatley says so well, the use of the superheater is increasing and is bound to increase. Probably no element in a steam plant to-day pays so high a return on the investment as the superheater.

The President:—Is there any further discussion on this interesting question? If not, we would like to hear from Mr. Oatley in closing.

Mr. Oatley:—I am pleased to have Mr. Lovekin submit the plate which he mentions, and which illustrates a modified arrangement of his superheater boiler. This will be substituted for the one shown in the paper. That which I used was the only one available at the time the paper was printed for distribution.

Mr. McFarland has expressed my sentiments very fully in his tribute to Mr. Isherwood. I fully appreciate the grand work which he has done in various lines, and especially with regard to his most carefully conducted and valuable experimental work along the lines of efficient use of steam. In the list given in my paper there was no thought of omitting any credit which we all know is due to Isherwood, but the names given in the paragraph referred to by Mr. McFarland and also in paragraph 27 were those of men who had designed and built superheaters, while Isherwood's connection with superheated steam was more that of an investigator and user of superheating apparatus.

Mr. McFarland's reference as to reasons why superheating remained quiescent for so many years are undoubtedly big factors, though I cannot help but feel that they were secondary rather than primary causes. I feel very sure that had some of the present designs of superheaters been available and had good steel castings and high grade steel in its various forms been at hand, the development and use of the superheater would have progressed rather than been crowded aside entirely by the introduction of the compound and later by

the triple expansion engine. In the absence of these materials, compounding, either in one or more stages, naturally became much more attractive.

It is flattering to the writer to feel that the discussion of this paper to-day has brought out so much that is in the line of agreement with the sentiments expressed in the paper. I believe that all of the speakers have expressed their belief in the coming of superheated steam, though the means for accomplishing it in the near future may not accord fully with the writer's personal views. It is also pleasing to have Mr. Anderson bring out a most important point in connection with the use of superheated steam in turbines. I felt that the paper was lacking in this respect, and as Mr. Anderson is probably one of the leading authorities in this country on turbine design I think his remarks are of particular value.

THE PRESIDENT:—I am sure the thanks of the Society are due and most willingly given to Mr. Oatley for his very interesting paper.

We will now take up the last paper to be considered at this meeting, No. 13, entitled "The Submarine of To-day and To-morrow," by Mr. L. Y. Spear, Member. In the absence of Mr. Spear, the paper will be presented by Mr. Eric H. Ewertz.

MR. ERIC EWERTZ, *Member*:—Mr. President and gentlemen, I wish that the author of this paper could have been here to read it himself, as he is ever so much better qualified to bring out all of the interesting points. In order to take up the least possible time I will read the paper in abstract, referring to what I consider may be of the most interest to you on this question of submarines.

THE SUBMARINE OF TO-DAY AND TO-MORROW.

By L. Y. Spear, Esq., Member.

[Read at the twenty-third general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 18 and 19, 1915.]

THE SUBMARINE OF TO-DAY.

In view of the very prominent, not to say leading, part taken by the submarine in the great struggle now raging in Europe, it is interesting to note that "the submarine of to-day" is for all practical purposes a development of the twentieth century only. At the opening of this century, the United States, France and Italy had just acquired the nuclei of their present flotillas; submarine construction had begun in Great Britain, while the other naval powers had nothing. At the present time this type is found in every navy. Owing to the secrecy imposed by war conditions, the number of boats built or building to-day is not definitely known, but the best information available indicates that about 350 have already been completed and that about 200 more are now under construction.

When we turn to examine the characteristics not only of the boats built in the past, but also of those now building, we are confronted with what at first appears as a bewildering confusion of types and sizes. On analysis, however, logical reasons are easily found for the existing variation in characteristics which in fact are due partly to considerations almost purely mechanical and partly to considerations which are purely military.

In the early days, the problem of the submarine designer was the production of a practicable boat suitable for harbor defense, a rôle which did not require high speed, long radius, or great sea-keeping qualities, and hence did not involve large displacement. The submarine, however, did not escape the general law governing the displacement of all naval types, and to meet the demand for increased speed, radius, seaworthiness and armament, it has been necessary to progressively increase the displacement. When the capabilities of the type had sufficiently increased, it ceased to be considered as suitable for harbor defense only and was assigned to the larger rôle of coast defense, and with further development it has come to be considered as an aid to the high seas fleet, as well as a useful weapon for independent offensive action in enemy waters.

As the submarine is dependent for propulsion both on the surface and submerged on special types of machinery, the rate of increase in displacement and military characteristics has necessarily been governed to a very large extent by the development of these features. As all naval powers carry on their lists numbers of vessels several years old, it follows that there are now many intermediate types in

existence (the result of gradual engineering development), which, though still useful, are not likely to be duplicated in the future.

At this point, a brief survey of what may be termed the mechanical development of the submarine seems desirable. The growth may perhaps be best illustrated by a comparison of the characteristics of one of the first successful boats with those of a recent type. The principal characteristics of these two designs designated as "A" and "B" are set forth in the following (Table I): —

TABLE I.

	Type "A," 1900	*Type "B," 1914*
Length	53′ 10″	230′ 6″
Beam	10′ 3″	21′ 6″
Surface displacement, tons	67	663
Submerged displacement, tons	75	912
Horse-power, surface	50	2,000
Speed, surface, knots	6	17
Horse-power, submerged	50	980
Speed, submerged, knots	5½	10¾
Radius action, surface, knots	200	3,000
Number torpedo tubes	1	8

At the date of the production of type "A," type "B" would have been an utter impossibility for lack of suitable propulsive machinery. As the equipment in each case represents the highest development of the corresponding period, the comparative figures given in Table II below are of interest as showing the improvement resulting from ten years of step by step development.

TABLE II.

	Type "A," 1900	*Type "B," 1914*
Horse-power main engines	50	2,000
Pounds per horse-power	78	48
Fuel consumption, pounds per horse-power	.74	.50
Horse-power electric motors	50	980
Pounds per horse-power	57	48
Pounds per horse-power of storage battery	909	216

As noted above, type "B," for the design of which the author is responsible, has been selected as fairly representative of the best results actually achieved to date in the mechanical development of the submarine. The representative character of the figures will be corroborated by an examination of the characteristics of the contemporary vessels in the English and German navies, viz., the English "E" class and the German "U-21 to U-32." Table III below gives the most important characteristics of these three designs, as well as such data as are available with respect to the German class "U-33 to U-42," which have been commissioned since the outbreak of the war.

TABLE III.

	Type "B"	*English Type "E"*	*German "U-21 to U-32"*	*German "U-33 to U-42"*
Length	230′ 6″	175′	213′	223′
Surface displacement, tons	663	730	640	665
Submerged displacement, tons	912	825	787	822
Engines	Diesel	Diesel	Diesel	Diesel
Horse-power, surface	2,000	1,600	1,800	2,300
Speed, surface, knots	17	15-16	16	17
Speed, submerged, knots	10¾	9-10	10	10
Armament, torpedo tubes	8	6*	4*	5*
Armament, guns	0	2	2	2

Counting then only such boats as are actually in active commission and of proved qualities, we may sum up this phase of the subject by saying that from the point of view of mechanical development "the submarine of to-day" connotes a vessel of the following approximate characteristics:

Surface displacement ..... 650 to 750 tons.
Submerged displacement ..... 800 to 900 tons.
Surface horse-power .....1,600 to 2,300.
Surface speed ..... 15 to 17 knots.
Submerged speed ..... 9 to 11 knots.
Armament .....2 guns of from 3 to 4 inches caliber and 4 to 8 torpedo tubes.

The wide radius of action of such boats and their efficiency when operating submerged at long distances from their base have been amply demonstrated in the present war. The exploits of the English "E" boats in the Dardanelles, the Baltic and the North Sea, and the similar work of the German boats "U-21 to U-41" in the North Sea, the Atlantic and Turkish waters, are too well known to call for detailed mention here, but it may be well to point out that the natural difficulties overcome by both sides have been enormously increased by the fact that the boats in order to reach their objectives have been required to make long voyages through waters controlled and closely patrolled on the surface by the enemy.

Having thus briefly examined the development so far accomplished on the engineering side, it is now in order to consider the present status from a purely military standpoint. From what has been said above, it is obvious that if smaller surface displacements than 650 to 750 tons are found in strictly modern boats, the reason must be sought on the military or financial side rather than on the engineering side. As a matter of fact, an examination of the characteristics of boats laid down during the past four years shows surface displacements ranging from 35 to 1,100 tons. Those of 800 tons and up properly belong among "the subma-

*Doubtful.

rines of to-morrow." The remainder when considered from the military point of view may be divided into three classes:—

First, the local or harbor defense submarine.

Second, the coast defense submarine.

Third, the offensive submarine.

The lines of demarcation between these different classes are in fact not very definite. Within certain limits, the harbor defense boats can perform the duties of the coast defense boats. Similarly, the coast defense boats can under certain conditions perform the duties not only of the harbor defense craft, but also of the offensive boats; and again, the offensive boat will usually be found quite well adapted for coast defense purposes.

Bearing in mind the fact that military considerations include financial ones, it is important to remember: First, that for defensive duties, the only armament of the submarine is the torpedo and its only fighting condition is the submerged condition; second, that in any given area, the greater the number of units, the more efficient the defense; and third, that increasing the displacement benefits the surface qualities more than the submerged qualities and armament, and, on account of increasing the cost, it decreases the total number of units available.

Taking all conditions into account and assuming substantial equality as to climatic and weather conditions, it would appear that for defense purposes only the most efficient size of unit is dependent on the extent of the coast to be defended. Of course the nature of the approaches to the coast, proximity of possible enemies, configuration of the coast, the location of immediate objectives for the enemy, and other considerations must enter into the matter, but not, it is believed, to the extent of vitiating the general rule. That recent construction programs appear to confirm this rule is perhaps best illustrated by the continued construction of the smallest type, for if we imagine the coast line to be contracted to a single harbor or bay, then the rule would call for the smallest practicable size, which type is in fact found among recent constructions. The only purely harbor defense units of modern construction of which the author has any knowledge were built from the author's design, and commissioned in one of the European navies in 1914. One of these little vessels has already demonstrated its usefulness by torpedoing an enemy destroyer and transport which ventured within its limited radius of action. The characteristics of this type, which was primarily designed for the defense of a certain harbor and bay, are set forth in Table IV.

TABLE IV.

Length	66′ 10″
Surface displacement, tons	35
Submerged displacement, tons	43
Engines	Diesel
Horse-power, surface	50
Speed, surface, knots	8
Radius, surface, knots	150
Speed, submerged, knots	6
Radius, submerged, knots	18
Armament, torpedo tubes	2

The conditions to be met in the defense of the limited coast lines of Holland and Denmark have resulted in the adoption of units larger than the pure harbor defense boat above described. The characteristics of the three designs employed for this purpose in the Dutch and Danish navies are given in Table V below. In connection therewith, it may be remarked in passing that vessels of these characteristics might prove very useful to the navies of larger countries for local defense purposes and that, therefore, their classification, whether as coast defense vessels or as local defense vessels, would depend not upon the characteristics of the boats themselves, but upon the duty assigned them.

TABLE V.

	Design No. 1	*Design No. 2*	*Design No. 3*
Length	98′	119′	116′
Surface displacement, tons	132	165	187
Submerged displacement, tons	149	204	229
Horse-power, surface	300	450	350
Speed, surface, knots	11	12	11.5
Radius, surface, knots	1,000	1,000	750
Speed, submerged, knots	8.5	8	8.5
Corresponding radius, knots	25	24	25
Armament, torpedo tubes	2	2	3

Turning now to the countries with long coast lines or scattered possessions, we find that, except where financial considerations are of very vital importance, the defense of the coast is now entrusted to vessels with a surface displacement ranging from 350 to 550 tons. The characteristics of some of the best known of such types are given in Table VI.

TABLE VI.

	U. S. "K" class	*English "D" class*	*French Pluviose class*	*French Brumaire class*
Length	153′ 4″	150′	—	—
Surface displacement, tons	389	550	400	400
Submerged displacement, tons	519	615	550	550
Engines	Diesel	Diesel	Steam	Diesel
Horse-power, surface	900	1,200	—	850
Speed, surface, knots	14	14	12.3	13
Speed, submerged, knots	10.5	8-9*	8	9
Armament, torpedo tubes (internal)	4	3	1	1
Exterior launching apparatus	—	—	6	6

The offensive submarine as it now actually exists is exemplified in its highest development by the boats of 650 to 750 tons surface displacement, the characteristics of which are given in Table III. This is not to say that some boats of smaller displacement are not playing the offensive rôle in the European war. In fact, the records appear to show that, under the conditions actually existing in Europe, smaller types can and are being employed usefully for this purpose.

In closing this part of the subject, the author wishes to emphasize the fact that the discussion has so far been limited to the submarines actually in active service to-day. The classifications made are admittedly not rigid. The limits to displacements mentioned in connection with the various classes are derived from a study of the actual facts from the point of view of the classification adopted. The primary object has been to outline briefly modern practice in submarine construction, particularly with reference to the smaller units, the design of which, owing to the present advanced state of engineering development, is now fixed almost entirely by military considerations.

THE SUBMARINE OF TO-MORROW.

Enough has already been said to indicate that, up to displacements of 750 tons and speeds of 17 and 11 knots, the designs of "the submarines of to-morrow" will be fixed, not by engineering limitations (as in the past), but by military (including financial) considerations.

Any opinion as to whether the very small harbor or local defense type is destined to be perpetuated lies outside of the scope of this paper, but it may not be out of order to venture a guess in the negative. At any rate, if this type is found in future naval programs, that fact will constitute a marked exception to the ordinary history of naval development. On the other hand, the coast defense and offensive types are sure of perpetuation. In fact, their value is now so fully recognized as to make it certain that present and future naval programs must in-

*Doubtful.

clude such boats in large and increasing numbers. It is also obvious from what has been said above that no standardization as to the size of future submarines is to be expected, since the most effective displacements must necessarily vary with the different conditions met in different cases. This being so, limitations of space here make it necessary to confine our further inquiry into the subject to the case of the United States.

At the present time, it appears to be the policy of the United States to employ the submarine extensively for coast defense purposes and also to construct it for offensive purposes, either in conjunction with, or independent of, the battleship fleet. In view of the great distances which separate us from the most of our probable enemies, and certain special characteristics necessary for the offensive type, it appears safe to conclude that in the immediate future at least two quite separate types will be employed, one of which we shall designate as the "defensive submarine" and the other as the "fleet submarine." While these two types may very well present marked differences in characteristics, nevertheless there are certain general conditions which in the nature of the case must apply to both, and therefore, before attempting to outline the probable future of each type, it will be well to give consideration to these basic conditions.

The outstanding features characterizing submarine warfare are the following:

(*a*) The submerged speed is necessarily inferior to that of the principal objective, viz., the enemy's capital ships.

(*b*) The protection of the submarine while engaged is independent of its displacement, except to the extent that increased dimensions impair handiness.

(*c*) The torpedo power is not proportional to displacement.

All of these considerations emphasize the importance of numbers. Financially speaking, however, large numbers involve limited displacement and hence (within limits) decreased efficiency of the unit. How is this basic difficulty to be adjusted? At first glance, the question seems too involved for any precise treatment, but on careful examination we find a reasonable basis for a solution in the fact that physical reasons, for the present at least, place a limit on the submerged speed of from 10 to 12 knots. As the chances for a successful attack on a moving target are so vitally affected by the submerged speed, it seems reasonable to adopt the practical maximum as a *sine qua non* and from that basis build up the design. As the torpedo is the sole reason for the existence of the submarine, it should not be too difficult to fix some irreducible minimum for the number of torpedo tubes, which in this case may be put at four. The third absolutely essential quality is the ability to pass from the surface to the submerged condition in a very short period of time. A precise limit as to the permissible period of time is difficult to set, but taking everything into account, we may here regard three minutes as the maximum permissible allowance. By eliminating all frills and non-essentials, it is possible to-day to secure these three primary qualities in a well-balanced design of about 250 tons surface displacement. Starting with this as the lower limit, let us now consider the additional factors, partly military and partly technical, which must determine the final solution.

Taking up first the remaining primary military features, viz., submerged radius, surface speed, and surface radius, we are confronted first by the fact that on account of the necessity for separate power plants, other things being equal, an increase in any one of these qualities can only be obtained by a sacrifice in one or both of the others. Keeping in mind the fact that a submarine on the surface has only a minor military value, it is natural first to set some reasonable minimum on the submerged radius. While opinions may well differ on this subject, the author holds the view that a radius of at least 100 miles at a speed of about 5 knots is necessary. This requirement by itself will not raise the minimum displacement figure above mentioned, viz., 250 tons, and will permit of a surface speed of from 11 to 12 knots, with a fuel supply corresponding to a radius of 1,000 miles.

Leaving aside for later consideration the question of the "effective" radius of action, which, in fact, involves much more than the mere fuel supply, let us briefly consider the effect on displacement of increasing the surface speed only. We have only to remember the intimate relation of length to speed to see at once that, while keeping the submerged qualities constant, increases in surface speed are expensive in displacement. Thus to increase the speed of the above primary design by 2 knots, it is necessary to increase the length from 115 to 145 feet and to increase the surface displacement from 250 to 325 tons, and an increase to 20 knots surface speed would involve a length of about 260 feet and a displacement of about 1,000 tons.

Increases in radius of action, in so far as the mere ability to carry the necessary fuel is concerned, do not make such great demands on displacement, but when all of the factors which in practice fix the "effective" radius are taken into account, the demands on displacement become astonishingly great. The "effective" radius is in fact that distance which the boat can run on the surface, taking the weather and sea as it finds them, and still arrive at its destination with the personnel in efficient physical condition for submerged work. In other words, habitability and seaworthiness from a habitability point of view are vital factors, so vital in fact as to warrant some detailed examination here.

In the case of the 250-ton primary design above referred to, about four days would be required to run out the fuel radius. Good practice then would require fresh water and provisions for a week, which might be taken as the limit of time for such a boat to be absent from its base and dependent entirely upon its own resources. If good weather or operation in sheltered water could always be counted on, the complement of such a boat could be organized in a watch in two and be thus reduced to a number for which it would be possible to provide living accommodations of an elementary character. Now let us assume that an effective radius of 3,000 miles is required. Obviously, such a radius involves work in the open sea with a possible period of independent operation of three weeks. Here a watch in three is at once indicated with an increase in the number of the crew of about 50 per cent. Moreover, the living accommodations must be much more elabo-

rate and the fresh water and provision supply must be four and one-half times as great. This, however, does not tell the whole story, since reasonably comfortable conditions for surface navigation for extended periods in rough water or very cold weather involve alterations in the design, which, if not compensated for by additional displacement, would reduce the submerged speed and radius. For instance, the percentage of surface buoyancy which would be adequate with a smaller radius would, other things being equal, not be adequate in the case of the larger radius. An increase in this, without increase in displacement, would involve a decrease in submerged speed and radius. Again, even if the supposedly fixed submerged qualities were sacrificed to increase the habitability, we must remember that absolute displacement is in itself a large factor. In other words, having in view the weather conditions which must be met, there is probably some minimum limit of surface displacement, even when substantial sacrifices of other qualities are made in favor of habitability.

Having thus briefly outlined the design problems flowing from the purely military considerations, let us turn now to the engineering questions involved. Assuming certain speeds, radii and armament as rigid requirements, it is obvious that the displacement must vary according to the type of machinery installed and the amount of attention paid in the design to questions of access and reliability. The most important items in this connection are of course the main engines and the storage batteries. In each case reliability and long life are in conflict with compactness and light weight. In these important respects, there is as yet no uniformity of practice in the different navies of the world. In certain continental countries, notably Germany, the extreme of lightness and compactness is sought, accessibility is sacrificed, and a very highly trained personnel is relied on for reliability. The wide range of practice is illustrated by the fact that the weight in pounds per horse-power of the main engines of the single-acting Diesel type almost universally used varies from 50 to 100. In the case of storage batteries, the weight per motor horse-power at the one hour rate of discharge varies from 131 to 253 pounds. The smaller figure represents the extreme case, where the durability of the battery is sacrificed to capacity. The heavier of the two batteries is in fact expected to have a service life at least three times as great as the lighter.

Quite aside from the type of machinery adopted, the matter of access and roominess in general is of great importance, and finally we must in addition consider the demands made by safety features, including elaborate bulkhead sub-division, as well as the installation of special fittings and appliances, such as submarine signals and the like.

To illustrate the aggregate effect of such considerations, we may compare a comparatively simple design of the date of 1910 with a very recent one. The early design has the following characteristics:—

Surface speed	14 knots.
Surface fuel radius	2,490 miles.
Submerged speed	11½ knots.
Submerged radius at 5 knots	110 miles.
Armament	4 torpedo tubes and 4 torpedoes.

The corresponding data for the later design are as follows:—

Surface speed	14 knots.
Surface fuel radius	3,150 miles.
Submerged speed	10½ knots.
Submerged radius at 5 knots	75 miles.
Armaments	4 tubes, 8 torpedoes and one 3″ gun.

It will be noted that the newer design provides for slightly greater armament with an increase in the surface radius. On the other hand, this has been compensated for by a decrease in the submerged speed and radius. Notwithstanding this reduction in submerged qualities, the surface displacement is increased 60 per cent. In this particular case, there is no material difference in the weight and space per horse-power of the main engines, and the very large increase in displacement has nearly all been absorbed by habitability and safety features.

The substantial influence of the type of main engines employed may also be best illustrated by an example from actual practice. In the case in mind, on a surface displacement of 350 tons, a trial speed of about 14½ knots was obtained with comparatively light two-cycle engines developing 450 horse-power at 450 revolutions per minute. The engines in this case weighed about 56 pounds per horse-power. When these engines were replaced by a heavy type weighing 86 pounds per horse-power and operating at 375 revolutions per minute, the trial speed was reduced to 13 knots.

Having thus briefly reviewed the main elements of the problem, we are now in a position to consider the probabilities with respect to the characteristics of the United States submarines of the near future. Let us consider first the question of the defense type. Adequate defense obviously requires the assembly of the requisite number of boats where and at the time needed. Broadly speaking, this may be accomplished in two different ways. The first method is in principle that of local defense embodying the permanent stationing of an adequate number of boats of moderate radius in each locality where protection is desired. With adequate numbers, this method can certainly be relied upon to prevent blockades, bombardments or landing operations. The second method involves abandoning altogether the idea of assigning groups of submarines for the defense of certain areas and using instead flotillas of larger boats which by reason of increased speed and sea-keeping qualities could be concentrated when and where wanted. Such flotillas could also carry the line of defense much farther from the coast, and in this way could co-operate more fully with

the battle fleet. Should this second theory be adopted, it appears certain that there would arise an imperative demand for much higher surface speeds, which, of course, would involve marked increase in the displacement and cost of each unit. At the present writing, the largest defense boats ordered by the United States are of about 500 tons surface displacement, with a speed of 14 knots. If the policy under discussion were to be adopted, it would perhaps be logical to pass at once to materially higher displacements and speeds, say 800 tons and 17 to 18 knots. Following the natural law of naval evolution which seems to look toward the attainment of the maximum power in each unit, we would expect to see this displacement and speed increase from year to year. Carried to the extreme and logical end, this policy would eventually result in a merging of the defensive type into the offensive type. When that point is reached, if ever, our present units would probably be assigned to local defense and their numbers would be supplemented by new constructions of moderate displacement.

Having in view the strong differences of opinion on the subject which now exist in the Navy, the author does not anticipate the definite adoption at an early date of either method to the exclusion of the other. In fact, if the past is a safe guide, we may expect our Navy Department to keep "in the middle of the road," thus avoiding all sudden radical changes. It followsthen that we may reasonably expect a compromise in the form of the construction of boats, which, while larger than necessary or desirable for local defense purposes, can still perform that duty, and at the same time possess the necessary habitability and the "effective" radius to enable them to keep the sea for long periods of time and to operate at a long distance from their base. Such a type would thus also be available for use according to the second method and on the whole should be very efficient for such purposes, since, on account of the moderate displacement involved, it will be practicable to compensate for lack of high surface speed by an increase in numbers. In fact, if an increase in numbers be coupled with adequate scouting service, the final efficiency obtained from a given expenditure may be greater if the speed of the flotillas is moderate than if it be high.

As noted above, the necessity for sea-keeping qualities will in itself place some lower limit on the surface displacement. Actual experience, which is really the only safe guide, appears to fix this limit at about 350 tons. In this connection, it may be interesting to note some of the most notable achievements of submarines in the matter of long voyages in the open sea. Some years ago, the U. S. S. Salmon, now the D-3, of 288 tons surface displacement, made a successful trip from Boston to Bermuda and return, the journey involving a stretch of about 700 miles from port to port. This year, a large number of submarines of 350 tons displacement have successfully crossed the Atlantic under their own power from Canadian waters, which performance, taking the number of boats and the length of the voyage into account, appears now to be a record. In the French Navy, the Faraday of 400 tons surface displacement has successfully made the passage from Rochefort to Toulon, a stretch of 1,730 miles. The voyages of the British "E" class from England to Australia, to the Dardanelles and to Russian Baltic waters, as well as the voyages of the

German boats around the British Islands and also to the Dardanelles, are all very convincing as to sea-keeping qualities. In these last cases, the average surface displacement involved is about 700 tons.

In the special case under consideration, the limit of permissible cost would fix the upper limit at say 550 tons. If we allow for the prevailing United States standards with respect to armament and the features affecting habitability, safety and access, as well as durability and reliability of machinery, a surface displacement of at least 500 tons is indicated.

Assuming that the military conditions can be met by an effective cruising radius of 2,500 miles at 11 knots with normal fuel supply, it will be interesting to set down some possible solutions where the submerged speed and radius and the surface speed are the only variables. In all these solutions, armament, safety, habitability and roominess are the same and the same character of machinery is contemplated, except where noted. The percentage of buoyancy is varied as it should be to meet the actual conditions as to surface speed and as to speed-length ratio.

TABLE VII.

	Design No. 1	*Design No. 2*	*Design No. 3*
Displacement, surface, tons	500	500	500
Buoyancy, per cent of above	20	24	28
Displacement, submerged, net tons	600	615	640
Surface radius at 11 knots, miles	2,500	2,500	2,500
Armament (all tubes internal)	4 tubes 8 torpedoes 1—3″ gun	4 tubes 8 torpedoes 1—3″ gun	4 tubes 8 torpedoes 1—3″ gun
Surface speed, knots	13	14	15
Submerged speed, knots	11	11	10½
*Submerged radius at 5 knots with			
Battery A	115	100	80
Battery B	132	115	92
Battery C	145	126	101

All things considered, the author believes that Design No. 1 presents the most valuable combination of qualities, but as this would involve a change in prevailing practice, it is perhaps more probable that the characteristics of U. S. coast defense boats of the near future will more closely approach Design No. 2. Whatever may be the decision of our naval authorities as to the surface speed necessary, the author is firmly convinced of the relatively greater importance of the submerged qualities for this type of boat, and consequently believes that battery capacity and submerged radius and speed should not be unduly sacrificed either in the interests of durability or first cost.

*Type A is a heavy durable battery with positive plates of the Plante type. Type B involves the use of thinner plates of the pasted type with a probable sacrifice in durability of about 50 to 60 per cent. Type C is of special construction equal to Type A in life, but more expensive, so that its use would increase the first cost of the boat by from 4 to 5 per cent.

In this discussion it has been assumed throughout that the type of machinery used, both for surface and submerged propulsion, viz., Diesel engines and electric motors, will be adhered to in the near future. The various substitutes which have been proposed, particularly with respect to the submerged power plant, are all as yet in the early experimental stage. Even should any of them achieve such success as to warrant the abandonment of prevailing types of machinery, the results will not show in the defense "submarine of to-morrow," but rather in "those of the day after to-morrow," which are beyond the scope of this paper.

It remains still to consider the offensive or fleet submarine. If this type is to accompany the battle fleet, a high surface speed is an absolute necessity and with this must be combined a long effective radius. The question as to whether the fleet submarine really belongs among "the submarines of to-morrow" or not depends upon the surface speed which is considered adequate. If a speed of from 20 to 21 knots will suffice, the answer is certainly "yes," but if 25 knots or more are required, there is, to say the least, serious doubt with respect to the matter.

As the crux of this question lies in the matter of the surface power plant, it is necessary now to examine this subject in some detail.

At the present time, almost all modern submarines depend for surface propulsion on Diesel engines, the only exceptions being a certain number of French boats equipped with steam engines. The Diesel engine is in fact the ideal motor for this purpose on account of the following qualities:—

(a) Compactness and moderate weight.
(b) Great economy in fuel consumption.
(c) Ability to start instantly.
(d) Ease in disposition of products of combustion.
(e) Freedom from excessive radiation or storage of heat.

In all respects, except quality (a), the Diesel engine is vastly superior to the steam engine and hence is to be preferred.

The conditions under which any engine must work in a submarine are very unfavorable. The space and weight available are strictly limited and the demand for speed often so insistent as to force the use of comparatively light-weight, high-speed engines. Complete reliability of operation under such circumstances can only be attained after an adequate period of development. The submarine Diesel engine, while a newcomer in the field, has even now been developed to a point where, for moderate powers, entirely satisfactory reliability is obtained, when extremes in the way of light weight and high speed are avoided. The best engineering talent in all countries is being devoted to the development of these engines, which is in fact making rapid strides. Up to the present time, the maximum power per unit which is actually in successful service is about 1,200 horse-power, but considerably larger units are under construction. As is natural, owing to the short time in which this type of engine has been under development, uniformity of practice has not been reached. In Germany, and in other continental European countries, except France and Russia, very high-speed, light-weight engines are most in favor with the two-cycle type generally pre-

dominating over the four-cycle, although many of the German boats are equipped with four-cycle engines constructed by the Augsburg Works, the others being equipped with two-cycle engines constructed by the Krupp and Nuremberg Works. In France and Russia, both two and four-cycle engines are employed and there is a tendency towards the use of engines of greater weight and more moderate speed. In England, the two-cycle engine has not found favor. Practically all of the English boats are equipped with four-cycle engines of moderate speed and weight. No effort appears to have been made to gain a slight increase in surface speed by the use of the lightest possible engines. In the United States, both two and four-cycle engines have been installed and in a number of cases the two-cycle engines have been of the high-speed, light-weight type. The tendency now is towards the use of a heavier engine of more moderate speed, a development which means an increase in the displacement of the boats in order to avoid a loss of surface or submerged speed.

The lightest Diesel engines so far employed weigh about 50 pounds per brake horse-power and operate at a speed of about 500 revolutions per minute. The heaviest engines weigh about 100 pounds per horse-power and operate at a speed of about 350 revolutions per minute. A fair average for single-acting engines of substantial construction and moderate speed may be taken as 70 pounds per horse-power. While future development will no doubt result in some decrease in weight without sacrificing durability or reliability, there is no reason to believe that the improvement in single-acting engines will be radical. Internal-combustion engines in general, however, have not yet by any means reached the limit of their development, and it is not unreasonable to assume that it will be possible to produce units of this type of great power of substantially the same weight and space as that required for steam installation and comparing favorably with the latter with respect to the matter of reliability.

In the present stage of development of the single-acting Diesel engine, it is entirely practicable to install a submarine power plant of from four to five thousand horse-power in a boat of from 900 to 1,100 tons surface displacement. When this displacement is coupled with a length of about 260 feet, a speed of from 20 to 21 knots can be obtained with the above power. When we come to consider the question of a speed of 25 knots or more, it is well to remember that excessive length in a submarine is in itself a very undesirable feature. In operating submerged, it is not always possible to avoid some fore and aft inclination of the boat's axis, and, when great lengths are involved, comparatively small angles of inclination result in great differences in the level of the bow and stern. Obviously, then, the greater the length, the greater the depth of water required for rapid and safe submerged maneuvers. On this account, having in view the possible and probable uses of the fleet submarine, every effort will no doubt be made to keep the length within reasonable limits. Adopting say 300 feet as the limit of length and coupling this with a displacement of about 1,200 tons on the surface, from ten to twelve thousand horse-power would be required for a surface speed of 25 knots. An installation of Diesel engines of such power would at this writing be experimental. It follows that, not-

withstanding its serious disadvantages for submarine service, submarine designers may in the immediate future be forced to employ a steam plant in order to meet the demand for a surface speed of 25 knots or more. With steam-driven vessels, to secure equivalent radius of action, the fuel supply must be at least double as compared with Diesel engined vessels. Taking this into account, it would appear that a speed of 25 knots, coupled with a radius of say 1,500 miles at full speed and 3,000 miles at 14 knots, cannot be accomplished on the above limit of displacement without a material sacrifice in submerged qualities. To illustrate this, let us take a concrete case. Starting with a Diesel engined vessel of 1,100 tons surface displacement and 20 knots speed, coupled with a normal fuel radius of 1,500 miles at full speed and 3,000 miles at 14 knots, and allowing 70 pounds per horse-power for the main engines, we arrive at a weight of approximately 220 tons for main engines and fuel. Now considering a steam-driven 25-knot boat of the same radius of action and corresponding speed and assuming that the machinery installation proper can be made on 45 pounds per horse-power, we arrive at a total weight of about 366 tons, or an increase of 146 tons. The increase of 100 tons in displacement will involve at least an increase of 40 tons in the weight of the hull and fittings, leaving us a net increase of not more than 50 tons. Hence, if we are to keep within the limits of the displacements mentioned, we must sacrifice the submerged qualities. Inferior submerged qualities are certainly serious defects from a military standpoint, but a danger of an even graver defect than a moderate decrease in submerged speed and radius is certainly involved in the installation of steam machinery. It has been pointed out above that rapid submergence is an absolutely essential quality and in this respect steam-driven submarines must inevitably be inferior to those driven by internal-combustion engines. Whether and to what extent the inferiority of the steam plant in this respect can be overcome remains entirely a question for the future, but it is certainly a fact that at the present time the difficulties have not been overcome in France, even in installations of comparatively small power. For the above reasons, the steam plant if adopted at all will be considered as a temporary expedient and the steam engine is certain to be displaced by Diesel engines as soon as the development of the latter permits the attainment of the surface speed required. Because steam units have been developed for other purposes to powers in excess of those which the submarine requires for a speed of 25 knots, it is often assumed that there will be no great difficulty in adapting the steam engine to submarine propulsion. In the author's judgment, this is an erroneous assumption, since, as a matter of fact, the adaption of the steam drive to the requirements of the submarine involves many a step in the dark and the attempt is likely to result in many disappointments. In fact, as indicated above, it is not beyond the bounds of possibility that the effort may result in complete failure, in that, while the surface speed may be obtained, other and vital military qualities may be sacrificed to such an extent as to make it impossible for the vessels to perform the service for which they are designed.

It had been the author's intention to supplement this discussion with some ac-

count of the efforts being made in Europe to develop the fleet submarine, and also to touch upon the possible effects upon such designs of the scouting and commerce destroying duties which might well be performed by this single type. The author regrets that a lack of time requires the termination of the paper at this point, and at the same time presents his apologies to the members of the Society for the sketchy nature of the paper which has been unavoidable under the circumstances of its hurried preparation. In view of the very great public interest in and importance of this subject at the present time, intelligent discussion by those capable of realizing the difficulty of the problems to be met is greatly to be desired, since from such discussion helpful suggestions are almost sure to flow. Should this brief survey of the present situation serve to provoke such discussion, the author will feel fully repaid for the work of preparation.

DISCUSSION.

Mr. Ewertz (after reading the abstract) :—What is true of the requirements in the United States is not true of the requirements in some of the countries of Europe. Mr. Spear has tried to describe what is useful here, there, and in other places. In the United States he is referring to two types, the coast defense, and the offensive or seagoing submarines. The boats which we have built up to date for the United States Government are practically all of the coast defense size, boats running up to 600 and 700 tons displacement. If we are to build offensive submarines, we must solve the question of surface speed, and while at the present time it is perfectly feasible to put two or more engines of from 400 to 500 horse-power in one boat, it is only possible with such size engines to get surface speed of from 20 to 21 knots. If you desire a submarine with a surface speed of 25 or 26 knots, the problem of developing power is one of the most important. As yet we have not solved this problem, and we may find it necessary to use steam for motive power. This has been experimented with from time to time, but up to the present no satisfactory result has been obtained by the use of steam installation.

There is probably no problem in regard to design that is so complicated as the design of a submarine. There are thousands of ideas as to what they should be like, coming from all parts of the world, and the designer of the submarine has to do the same as is done in other lines of business—he has to take the better points of the various suggestions and compile them into one design, a design that does not fulfil everybody's requirements, but is a compromise of all.

The success of submarines in the future will depend upon the willingness to concentrate our requirements along certain fixed lines, and if in this country we need coast defense and seagoing submarines, all our talents should be directed along the line of developing these two types of boats.

In a later part of the paper the author refers to the complications in connection with

the design of a seagoing boat. If you want high surface speed you must sacrifice submerged speed, and, on the other side, if you want submerged speed the surface speed must be sacrificed. You cannot have both of them at the same time in the same boat, due primarily to the distribution of weights.

THE PRESIDENT:—Gentlemen, we have before us the paper entitled "The Submarine of To-day and To-morrow," by Mr. L. Y. Spear, which has been presented by Mr. Ewertz.

MR. PHILIP B. BRILL, *Member:*—I would like to ask the gentleman if he can give me a little information on two matters appearing in this paper. In Table I, page 202, type "B," the surface displacement is given as 663 tons. The submerged displacement is 912 tons. That gives a reserve buoyancy of 249 tons, or 37.5 per cent of the surface displacement. I would like to ask whether the paper as printed is correct, or whether there has been some typographical error. The buoyancy appears to be——

MR. EWERTZ:—I am not in a position to answer that question, as I have not gone over this paper with the author. I had the pleasure of reading it here, and that is as far as I have gone with it.

I suggest that the Secretary be instructed to ask the author of the paper that question in behalf of Mr. Brill.

MR. BRILL:—There is another question with reference to matter on page 206, which is of the same nature, and I judge probably the gentleman would not be able to answer that if he could not answer the other question.

THE PRESIDENT:—You might give it to the Secretary, and it can be transmitted to the author at the same time. Indicate what the question is.

MR. BRILL:—On page 206, Table VI, in the U. S. "K" class, the surface displacement is given as 389 tons, and the submerged displacement is 519 tons, or a reserve buoyancy of 33 per cent. That is possible, depending on the condition of load, and I would like to ask what is the condition of load in the surface displacement given, as to the fuel carried and the corresponding surface radius of action.

Also, in regard to type "B" on page 202. the surface radius of action is stated as 3,000 knots. I would like to ask at what speed that radius of action was made.

MR. ELMER A. SPERRY, *Member:*—This is a very important and timely paper, and I hope it will be quite fully discussed. We need all the light on the subject that we can get. The weak points in the submarine to-day are known to be the motive power, and the fact that the submarine has no eye. It is barely possible that in the near future we will find a way to throw a beam out ahead of the submarine so that it can see. Think of the situation of the men who man these submarines, when they are about to emerge from the water, and think of the three or four accidents, very serious ones, that have occurred in England especially, when they have emerged up under a ship and suffered injury. The submarine is very sensitive, the plates are only one-quarter or three-eighths of an inch thick, and any small injury is likely to sink it immediately.

We have made one contribution, possibly, in this country, towards the navigation of the submarine. You understand that when an electric cable has direct current flowing through it the cable itself becomes tremendously magnetic. At Niagara Falls not long ago they had an experience showing how magnetic a harmless copper cable may become. There was a tunnel containing cables on either side, which conveyed current to Buffalo. On the Buffalo lines one sleety night they had a short circuit, and the onrush of current through the cables was such that it ripped the cables from their moorings, some 12 feet apart, and in their tremendous rush together they killed a man who happened to be going through the tunnel at the time. That was simply by virtue of the magnet lines of force about a cable.

In direct current—and all storage batteries must have direct current—there is a magnetic circulation about every cable that is constantly in one direction, and will easily turn a magnetic needle "in a ten-acre lot," the magnetic needle in a compass. When you have a compass in the small confines of a submarine, you cannot get it in a ten-acre lot. As soon as you put 3,000 or 4,000 amperes through any of the cables, the needles in the compass go around, and it never goes clear back and the directional function is lost. Another system of guiding the submarine has been sought and found, and now we have gyro-compasses, which are manufactured here in New York, on the submarines of nearly every navy in the world, and they are found to be reliable and useful. Some tests were made not long ago with that compass on the submarines that went in through the Dardanelles, under the mine fields, and into the Sea of Marmora, and one of them remained there four weeks, had the compass running every second of the time, and was able to get only two sun readings in that four weeks. The commander reports that each time when he could take an observation he found himself exactly on the scratch line. It is a comfortable feeling for those in a submarine to know that they have a compass upon which they can rely.

The compasses were installed on these submarines that went to join the Russian fleet and made a journey of 1,600 miles, in which many difficulties of navigation were encountered, and the compasses were found to be reliable and very accurate. Some of these officers have received Victoria Crosses, and a number of letters have been received expressing very cordial appreciation of the gyro-compass and satisfaction that they were able to navigate the submarines so satisfactorily.

The gyro-compass makes it possible to do another thing which is very valuable in connection with the torpedo fire from a submarine. That is, we put a repeater compass—you understand the master compass is usually not used directly—we have repeaters which are coupled with the master, the accuracy of which, in following the compass, is 1/12 of a degree, a time lag of .001 of a second. We hang one of these around the skipper's neck, and he has a little repeater right before him with a 26-foot flexible cable on it, permitting him to go into the prow of the submarine and stand with his thumb on the air discharge valve of the torpedo tube, so that after he has been up and taken a last bearing of the target with the periscope and knows that he is within the yawing angle, then when the submarine gets exactly to say 71¼ degrees he is enabled to instantly discharge his torpedo and gets practically 100 per cent hits. If he has a torpedo in the tube, it will go straight, because the aim of that torpedo is due to the aim of the submarine and this is dead accurate. We feel we are well along with one problem—a serious one, too—and that is this aid to navigation.

We believe that the same progress is going to be made in reference to the engine. This paper states that the present Diesel engines require between 50 and 60 to 100 pounds per horse-power. That is a serious objection to the Diesel engine, and it is felt that some improvement should be made in this line.

The material efficiency of the Diesel engine is extremely low. A great quantity of metal has to be put in the engine to take the pressures that come up instantly, and come down almost on the same curve—a very small percentage of the total time, less than 7 per cent in the two-cycle and 3 per cent in the four-cycle engine, and all the metal there for that brief period of time.

If a much larger mean effective pressure could be obtained so as to cut down the material incidental to a given motive power, a great advance could be made. Let us hope that someone will be able to do this, or someone will make a suggestion by means of which it can be done.

Another great trouble is the storage battery. Whether an Edison battery or a lead battery, it is found to be very heavy as compared with the horse-power it is capable of giving. The lead battery has shown superior qualities in the even discharge line as compared with the Edison. I believe that gives quite a different line. Of course, the trouble with the Edison cells, again, is that you must have almost twice as many of them, and very much less power for a given cost, so that as regards the motive power we are up against a number of problems. We need suggestions of improvement in this respect, and it is just such discussions as this to-day that is necessary. No matter whether a man has a good idea or a poor one, it is wise to get up and air it. It may lead to something better and he will certainly be appreciated, I am sure.

Mr. Wm. T. Donnelly, *Member*:—I do not know that I can add anything to the paper as it is very comprehensive, but I should like to say something relative to the fundamental principles involved from a combined mechanical and dynamic engineering point of view.

The most discouraging thing about the Diesel engine to mechanical engineers has been its excessive weight per unit power delivered, and this has been brought out very clearly by Mr. Sperry's statements.

Every Diesel, and in fact every internal-combustion engine, depends upon itself for the compression of air used as a source of oxygen to consume the fuel supplied by the oil. All of us who are familiar with the card of a Diesel engine know how much of the area is taken up by the work represented in compressing the air, and the fact needs no emphasizing that, if this area could be represented by useful work, the output of the engine per unit of weight will be very much greater. The question from a mechanical point of view is: It is possible to provide the compression of the air by an exterior device of very much less weight, so that, having the air compressed, the output of the Diesel engine cylinder would be the complete area of the card below the expansion line?

Considered from a thermo-dynamic point of view, the cylinder of a Diesel engine, heated from previous explosions, compressing the air in a single stage without cooling, is a very wasteful form of air compression and one that could not be tolerated in any industry demanding a large amount of compressed air.

As a matter of fact, submarines as now constructed have entirely independent air compressors, capable of delivering air at a sufficiently high pressure for the Diesel engine, and all submarines have, or can be provided with, tanks of large capacity to hold this air under compression.

Even if this method of operating a Diesel engine was used only for emergency runs—that is, when the very highest speed on the surface was necessary—it would be of very great importance, and, if air previously stored up could be used for this purpose, it would enable

the charging of the batteries to be accomplished in a much shorter time where the charging was of supreme importance to enable the submarine to again operate electrically below the surface.

Thermo-dynamically it should be pointed out that it is not primarily the fuel but the amount of oxygen in a cylinder charge of air which limits the power of the engine. This raises the question of the possibility of increasing the oxygen contained in a given amount of air. The pre-compression of the air and the reduction of its heat content before its introduction into the working cylinder would make it possible to add a considerably greater amount of heat without increasing the initial temperature above that found to be the limit in the present practice. The amount of this heat is that represented by the mechanical energy used to compress the air, and is of very considerable amount.

Another matter which should receive careful consideration from a thermo-dynamic point of view is that of running the compression to a sufficiently high degree to start combustion. This from a mechanical engineering point of view is an absurdity. It is so easy to obtain an initial temperature by electricity, and its control is so positive, that the matter of initial compression to combustion temperatures should be eliminated from the Diesel engine problem.

The matter of injecting other material into the cylinder after the heat has been generated to carry out and increase the mean effective pressure is another point which should be investigated, and it should be pointed out that past investigation has been altogether too much controlled by the desire for very high thermal efficiency. Thermal efficiency is of very great importance, but is relatively of small importance in a submarine, the power problem of which we now have under discussion.

I am very confident that there are possibilities in the Diesel engine far beyond the present developments, and they will be discovered and developed by working along special lines such as the application to the submarine, where the demands are quite different to an engine used in industrial purposes working perhaps twenty-four hours a day, and therefore consuming a very large amount of fuel, the cost of which becomes the most important item in the problem.

Beyond question, the most important consideration in the Diesel engine as applied to the submarine is that of increasing its output per unit of weight, and one of the first things to be sacrificed in attaining this end is its very high efficiency. From the fact that the cost of fuel for operating the engine of a submarine is probably the very smallest item to be considered and of relatively small importance, I would ask the mechanical and thermo-dynamic engineers for the time being to disregard thermal efficiency and concentrate their attention on the purely mechanical efficiency which we find so exceedingly low in the Diesel engine.

Mr. John F. Wentworth, *Member*:—The problem of the submarine is out of my line. The heart of the submarine, the internal-combustion engine, is, however, my specialty. I came as an interested listener to get information upon the subject of submarines. The queries of Mr. Sperry relative to the possibility or desirability of reducing the present stresses in the oil engine, and of Mr. Donnelly relative to the desirability of searching out some method for increasing the mean effective pressure of the oil engine are particularly interesting subjects to me, inasmuch as I have spent a good deal of time in the hopes of solving these two problems.

First I would like to take up the question of stresses in the engine which make the pres-

ent engine so heavy. At the present time I am engaged in the design of an engine based upon my theories, which differ very materially from the theories of the late Dr. Diesel. As a result of correspondence with the Navy Department relative to the discrepancy of data quoted last year for the two ships, the Cyclops and Jupiter, my theories were mentioned and I was invited by the Navy Department to design an engine to illustrate my theory. The option was given the Department to select as a problem either a large sized engine or a submarine engine. The submarine engine was selected. In this selection I was somewhat limited in size and power. However, I decided to conform to requirements as far as possible, but not to sacrifice any desirable elements of my design to conform to the restrictions.

The type of engine selected to submit was the low-pressure type. In this engine the clearance of the cylinder is about 17 per cent in place of 8 per cent, as is used in the Diesel engine. In order to produce initial ignition of the fuel it is proposed to use steam in the jackets of the cylinder. The explosion pressure can be allowed to run up from a pressure of 175 pounds to around 500 pounds. In this case the engine would at first thought appear to be no lighter than the Diesel. This is not the case, however, as the weight of the engine is due in no small degree to the bearing areas. In the Diesel, with its high pressure of compression, a lower bearing pressure per square inch must be used than in the proposed type where this stress, if it exists at all, will exist for only a short time. It is my opinion that much of the massiveness of the present Diesel engine is unnecessary. This applies to the cylinder. The part of the cylinder exposed to the maximum stress is the top. Here we have a solid ring of metal where the head and cylinder join. This is a great aid in resisting the bursting effect of the cylinder. As for the holding-down effect it is necessary only to assure a ring of metal sufficient to resist the effect of the maximum stress on the piston as a tensile stress. As for the head of the cylinder its depth necessary to allow for passage makes it well reinforced. The problem seems to be more one of design to assure maximum reliability in regard to the quality of the castings. As for the cylinder barrel I have considered the use of cast steel cylinder castings with cast iron liners forming the wearing surface. By some such care as this it seems no more than reasonable to lighten the engine to a considerable degree. It hardly seems feasible to lighten the engine by anything which will approach the constant pressure type which I worked on for some time and concerning the undesirability of which I have assured myself. The weight of the engine must not be reduced at the expense of its efficiency or general utility.

The other point was that brought up by Mr. Donnelly in regard to the possibility of in some way storing up air in a highly compressed form for the purpose of running on oil power submerged and also to increase the mean effective pressure. I was much pleased to have Mr. Donnelly bring this point up. He very correctly said that in a given cylinder only a certain amount of atmospheric air could be compressed. With this amount of atmospheric air but a certain amount of fuel can be used. If more fuel were injected the results would be imperfect combustion without any increase in the power. This is one of the points which I have recognized and worked on, and this is the reason for my taking up the low-pressure type of engine. Let us assume that we have a Diesel engine of such proportions that the piston displacement is but one cubic foot. Then with the clearance space filled with pure air the contents of the cylinder will be 1.08 cubic feet. This is the most favorable case where the scavenging air is used to good effect. The limit of power in this engine will be that which can be derived from the use of that oil which will require 1.08

cubic feet of free air for its combustion. In the low-pressure type of engine which I am designing for the Navy Department, the clearance will be about 17 per cent, and in a cylinder with the same bore and stroke there will be 1.17 cubic feet of free air at the beginning of compression. I think that Mr. Donnelly will agree with me in my contention that the output of power in my type of engine will be over 8 per cent greater than in the Diesel of the same size. When I first proposed this type around 1905 the objection of the original Diesel manufacturers was that this engine would have some good points, but it would be more bulky than the Diesel. This proves the contrary to be the case.

Mr. Donnelly did not bring up the matter of efficiency, nor did Mr. Sperry. For this reason I will not say much on this point. It will be sufficient to say that this engine which I have originated will avoid the slow feeding of the fuel and in this way will gain in efficiency over the Diesel. The Diesel idea of slow feeding was originated as a result of the Diesel fallacy, which has since been abandoned by the engineers who have made a study of the oil engine. The slow-feeding doctrine is the vermiform appendix of the oil engine.

There is a feature which has been brought into my engine in order to produce the desired result in regard to obtaining a low-pressure type of engine, and this feature has other uses. For instance, it is necessary to warm the engine in order to use low-compression pressures. The only practical way to accomplish this seems to be by the use of steam in the jackets of the engine. This steam must be first produced by the combustion of fuel. The supply of steam can be maintained by the waste heat of the engine. Now we have a supply of heat on the submarine. Is this steam of any use? Mr. Spear and his engineers say "No." I say "Yes." Perhaps there has been a change of heart in the submarine builders in the last five years since this proposition was put up to them. At that time I do not believe they even dreamed that submarines would cruise 1,000 miles. They do, however, and have developed into real ships in the broadest sense of the word and are no longer dispatched for a short dash to perform a special mission and return to their base. A military element must be capable of performing its function regardless of conditions. Can the crew do their best work if they are confined in a cold, damp vessel? Will it not be a godsend to the crew if they can have properly heated quarters, and will not the result of this physical comfort be manifested in their spirit and accomplishments? I believe this will be the case. Then again, might it not be advisable to give the submarine the ability to make a short spurt of extreme speed while submerged? This could be of use either for the offensive or for seeking safety. This can be done if there is a steam supply, by running the oil engines as steam engines from the steam supply at the same time the motors are running. In this way the maximum speed of the submarine while submerged can be greatly increased. When I was a student in the naval architectural course at the Massachusetts Institute of Technology I was taught that the limit of speed of a ship was caused by the wave-making resistance. I was taught that up to a certain point the power needed practically depended upon skin friction, but that above a certain point the wave-making resistance came into consideration, and the result was that further speed was at the expense of an excessive amount of power. Certainly a submarine should eliminate this wave-making resistance to a certain degree, at least while submerged. Might it not be possible to attain a greater speed submerged than on the surface? This speed could be maintained for only a short time and it might not be a valuable factor. This is a problem for the strategist and not for the engineer. The engineer can give the strategist the burst of speed if it is desired.

There is another point in connection with the present submarine engines. They are

advertised to use fuel oil. If we read about the engines we learn that they will use anything in the way of fuel. It is a fact, however, that the engines actually demand a high grade of fuel. The fuel is known as a "gas" oil. I understand that this oil is the product of distillation above kerosene. However the fuel is produced it is a special fuel and very free flowing. On the other hand the fuel used under the steam boilers is the residue from distillation. It seems to me to be a very weak point in the Navy to use two fuels. Obviously the steam vessels cannot use the "gas" oil, so it is up to the oil engine to use the heavy fuel. This is perfectly practical, but it requires a knowledge of the conditions, and the designing engineer must be divorced from his Diesel fallacies before perfect results can be obtained. This fuel in the steam vessels is heated before being fed to the furnace. The idea is to render the oil free flowing. The same method can be used in connection with the oil engine. Some time ago I recognized this fact and filed an application for a patent upon an engine in which I provided a tank in which the fuel could be heated in the same manner as it is now heated on the steam vessels. This application has been granted recently and will go to issue November 30. This feature will be incorporated in the engine being designed for the Navy Department.

The strategic value of this point seems to be considerable. A submarine running short of fuel and a long way from her base could procure sufficient fuel from any friendly ship she meets. Then the Navy Department will be able to standardize its fuel to the extent of eliminating one type of fuel from its stores. This, of course, is a step in the right direction.

It is hoped that Mr. Sperry and Mr. Donnelly may be more or less satisfied with my answer to their questions and that the members of the Society in general may give the advisability of the use of steam in connection with the oil engine some consideration.

Mr. Spear (Communicated) :—Mr. Brill has asked whether the information as to surface and submerged displacement of type "B" in Table I, page 202, is correct. The answer is "Yes." He has also asked for the speed corresponding to the surface radius at 3,000 knots of the same design. This speed is 10 knots. In reply to his third question with respect to the surface condition of loading of the "K" class, I would say that the displacement given, viz., 389 tons, is the full-load displacement corresponding to a complete supply of torpedoes, stores, fuel, lubricating oil, etc. The corresponding radius of action of this class of boat is 3,150 nautical miles at a speed of 11 knots. A greater radius than this is obtained when using certain reserve fuel tanks, the contents of which are, however, not included in the above given displacement of 389 tons.

The President :—The thanks of the Society are due to Mr. Spear for this paper, and we also thank Mr. Ewertz for presenting it.

Our schedule is completed, and I feel we can congratulate ourselves on the quality of the papers which have been placed before us, and that during these two days we have had an opportunity to renew pleasant acquaintances and benefit by discussions of a highly professional value. Our annual meeting ends tonight, when we meet to dine and lay aside for the time being our technical duties. We can simply be good fellows and enjoy a good time.

Mr. Stevenson Taylor asks for the floor.

Mr. Stevenson Taylor, *Past President*:—Mr. President and gentlemen, before we close this meeting, The Society of Naval Architects and Marine Engineers has a very pleasant duty to perform. The ill-health of the president since his election has prevented him from

presiding at our meeting until this time, but he has presided over the meetings of the Council as well as the meetings of the Society with admirable skill and dignity. With your permission, Mr. President, I will ask that a vote of thanks be given to you on your retirement. This retirement does not take place until December 31, next, but, fellow members, we will have no other opportunity in official manner to present such a vote to him in person.

I therefore ask that a vote of thanks be given to President Thompson for his charming and tactful manner in presiding over our deliberations, and for his valuable interest in the Society, which we hope he will continue.

Chief Constructor Washington L. Capps, *Vice-President*:—I desire to express my hearty concurrence in the words of appreciation and to second the motion of our President-elect, Mr. Stevenson Taylor. In this connection, I also take the opportunity of assuring our out-going president that we never let go of good things. Our past-presidents are eligible to continued hard work, and we shall look forward to the pleasure of Colonel Thompson's presence and assistance on many occasions in the future.

Mr. Stevenson Taylor:—I will ask for a rising vote. (The members rose.) There is no opposition, Mr. President, and I have the honor of presenting to you the thanks of the members of The Society of Naval Architects and Marine Engineers for your efforts in behalf of the Society during the term of your presidency.

President Thompson:—Gentlemen, it is idle for me to say that I thank you, but I do thank you from the bottom of my heart. I thank you for your kind reception. I thank you, as I have already done at this meeting, for the consideration you showed me during my illness.

Replying to Admiral Capps, I only want to say, if my health and my life are spared, there is nothing that this Society can ask of me that I will not give.

Gentlemen, I bid you good-bye, until we meet again around the table; and "may God be with you till we meet again."

The meeting then adjourned.

Deaths, 1915

JACOB ROBINSON ANDREWS

Jacob Robinson Andrews was born in Bridgewater, Mass., on September 6, 1861, and died in New York City on March 25, 1915, in the fifty-fifth year of his age. He was educated at the Bridgewater Academy and High School. Of a mechanical turn of mind, he early determined to go into the manufacture of machinery and, going to Bath, Maine, in 1879, served his apprenticeship in the shops of the Hyde Foundry, afterwards the Bath Iron Works, at that place. He soon attracted the attention of Gen. Thomas L. Hyde, was rapidly advanced to the position of foreman, and when, about 1888, the company determined to go into the manufacture of windlasses, steerers and other auxiliaries for ships, he was given entire charge of that department; and so successfully conducted its affairs that when, a few years later, its rapidly growing business required the formation of a separate company to handle it properly, the Hyde Windlass Company was organized and Mr. Andrews became its vice-president and general manager. A separate plant was built at Bath, which has become one of the most complete shops in this country. A foundry was added, and he perfected a metal known as Hyde Manganese Bronze, for propeller wheels and similar work, in which a very large business is done.

Mr. Andrews had a very large acquaintance among marine interests of all kinds, and was a welcome visitor in every shipyard office in the country. His acquaintance with officers of the navy, senators and representatives at Washington was also very extensive, and in all matters of legislation affecting the vessel interests or the larger questions of the marine policy of the country his knowledge was very wide, his views very broad, and his influence very great. Always ready to go to any trouble to do anything for a friend, his genial nature, unfailing good spirits and great ability endeared him to his associates in every way and his death will be greatly mourned, while American shipping interests have lost a most earnest and untiring worker.

Mr. Andrews married, on April 4, 1884, Miss Annie M. Shannon of Bath, who, with one daughter, Mrs. Rodney E. Ross of Bath, survives him.

His beautiful home in Bath was filled with a valuable collection of pictures, rugs and bronzes, and he was recognized as an authority in those arts and a discriminating collector. Mr. Andrews had been, for several years, president of the First National Bank of Bath. He was a member of many clubs, of the American Society of Mechanical Engineers, and an associate member of the Council of this Society.

RANSFORD D. BUCKNAM

Ransford D. Bucknam was born in Hantsport, Nova Scotia, in 1869, but was brought to Mount Desert, Me., when still an infant. When he was four years old his father was lost at sea. While still a lad he secured a place as a cabin boy on a ship plying the Great Lakes. After two years he shipped from Boston on a steamship bound for Australia, and was shipwrecked on the north coast of that continent.

Returning to the Great Lakes carrying trade, he became master of a whaleback, was promoted to be manager of the Alexander McDougall fleet and superintendent of the American Steel Barge Company. He next entered the employ of the Pacific Mail Steamship Company and was first officer of the City of Pekin, when he was offered the position of marine superintendent of the Wm. Cramp & Sons Ship and Engine Building Company. He commanded the U. S. battleship Maine No. 2 on her trial trip and the cruiser Medjedia, which the Cramp Company built for the Turkish Government and agreed to deliver to them. The Medjedia arrived in the Bosphorus on July 4, 1904, and the Sultan retained him as naval expert to teach the Ottoman sailors how to handle a warship and to shoot accurately. For his services to the Sultan he was decorated with many medals and the insignia of the order of the Osmanieh.

After the overthrow of the Sultan (Abdul Hamid), Admiral Bucknam was retained in the service and was the leading authority at the Turkish Admiralty during the Balkan wars.

Admiral Bucknam died on March 27, 1915, in Constantinople.

AUGUSTUS JAY DU BOIS

Augustus Jay DuBois was born April 25, 1849; was graduated from the Sheffield Scientific School in 1869, and was awarded the degree of civil engineer in 1870 and the degree of doctor of philosophy in 1873. Later he studied mechanics for two years at the Mining Academy in Freiburg, Saxony, and from 1875 to 1877 he was professor of civil engineering and mechanical engineering at Lehigh University. In 1877 Professor DuBois was appointed professor of mechanical engineering in the Sheffield Scientific School and in 1884 was transferred to the professorship of civil engineering, which position he occupied until his death.

Professor DuBois was the author of some of the best-known treatises on mechanics and stresses in the English language. His book on "Graphic Statics," published in 1876, was largely instrumental in introducing to American engineers the graphic method of determining stresses in framed structures now so widely used. This was followed by his translations of Röntgen's "Thermo-dynamics," Weyrauch's "The Calculation of the Strength and Dimensions of Iron and Steel Construction," "Hydraulics and Hydraulic Motors," and "Heat, Steam and the Steam Engine" from Röntgen's "Mechanics." In 1883 his elaborate and original book on "Strains in Framed Structures" took its place as one of the most important contributions to engineering literature, being perhaps the first comprehensive treatment of the subject. A series of books on mechanics culminated in his "Mechanics of Engineering," published in 1901.

Professor DuBois was a member of this Society and of the American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Institute of Mining Engineers, the Connecticut Society of Civil Engineers, the Society for the Promotion of Engineering Education, etc.

He died October 19, 1915.

CHARLES ANTHONY HARRINGTON

Charles Anthony Harrington was born on June 29, 1880, at Fall River, Mass. On March 10, 1915, he died from tuberculosis at the Naval Hospital, Las Animas, Colo.

He was appointed to the Naval Academy from Fall River and entered the service as a naval cadet on July 2, 1900. On February 1, 1904, he

graduated, standing ninth in a class of sixty-two members. He was sent to sea, and while a midshipman performed duty on the Alabama, Eagle, and Dixie. On February 1, 1906, he was appointed an ensign, and until August 25, 1906, continued his sea duty. On that date he was assigned to duty in the construction corps of the navy, and in the fall commenced the usual graduate course for members of that corps at the Massachusetts Institute of Technology. He completed this course on May 15, 1909, and upon graduation was assigned to duty at the navy yard, Portsmouth, New Hampshire.

While on duty at Portsmouth he took a great interest in all matters having to do with the scientific study of shop management and contributed a number of articles on this subject to the technical and scientific press.

After three years in Portsmouth he was taken seriously ill with tuberculosis, but in a six months' sick-leave apparently completely recovered his health.

He was then given temporary duty as inspector of hull material for the United States Navy in Pittsburgh, in which position his work was of great value to the Navy Department. After seven months he was transferred to Long Beach, Cal., as superintending constructor for submarines building at the works of the Craig Shipbuilding Company.

After less than a year in this position the old tubercular trouble returned, this time so seriously that he was with difficulty transferred to the hospital at Las Animas. There he remained until the time of his death on March 10, 1915.

Throughout his life, both personal and official, Assistant Naval Constructor Harrington followed the highest ideals. He was energetic and imbued with a high sense of duty. Should his life have run the normal term he would undoubtedly have made a most enviable name for himself.

HENRY SELBY HAYWARD

Henry Selby Hayward was born in Brooklyn, N. Y., September 19, 1845. His parents moved to Elizabeth, N. J., in 1852, and he was educated at the Rev. David H. Pierson's School in that city. Later he took a course in mechanical drawing at Cooper Union, New York City. In 1862 he entered the Novelty Iron Works in New York City and served four years' apprenticeship in marine construction work and engineering. In 1866 he

entered the service of the Pacific Mail Steamship Company, and made the voyage on the steamship Montana through the Straits of Magellan to San Francisco. He returned to New York by way of Panama. In 1867 he again went to San Francisco, this time as assistant engineer on the steamship Grand Republic. She sailed in September, 1867, as the first regular steamer on the Japan and China route of the Pacific Mail service.

Mr. Hayward returned home in November, 1872, on three months' leave after six years of continuous service, advancing to the position of acting chief engineer before his return, but while home decided to resign and entered the service of the Pennsylvania Railroad Company, April 1, 1873, as machinist in the Altoona shops. He was subsequently detailed to duty in the draughting room, and in 1874 detailed for special duty on the United Railroads of New Jersey Division with title as assistant road foreman of engines. He was appointed assistant superintendent of motive power April 1, 1875, to which the supervision of the marine department was added in 1881. On October 1, 1882, he was appointed superintendent of motive power of the United Railroads of New Jersey Division; he was also made superintendent of motive power of the West Jersey Railroad in 1883, and of the Camden and Atlantic Railroad, including the ferries and floating equipment on the Delaware River, in 1884. He had supervision of the motive power and marine equipment of the New York, Philadelphia and Norfolk Railroad from January 1, 1890, until his death. During the eighties he took out several patents, including interior check valves on locomotives, one for car journal box, another a cut-off valve for marine engine. This cut-off valve was largely used by the various ferries in New York Harbor.

He was a member of this Society and of the American Society of Mechanical Engineers, the Engineers' Club of New York, Engineers' Club of Philadelphia, American Railway Master Mechanics' Association, Master Car Builders' Association, and the New York Railroad Club.

JOHN BROWN HERRESHOFF

John Brown Herreshoff was born in Bristol, R. I., in 1841. An attack of infantile glaucoma destroyed his sight, but his education was carried on in the schools of his native town. His bent for mechanism revealed itself at an early age, and the handicap of total blindness seemed to serve as a spur

to his tireless energy. The miniature craft that he built and rebuilt in those early years served as the foundation of the skill and knowledge that he later turned to such good account.

At the age of twenty he began the construction of larger craft, and in 1863 he embarked on naval construction as a business, which he carried on for more than fifty years.

In 1872 he entered into partnership with his brother, and together they designed and constructed for the U. S. Government the first torpedo boat, the Lightning.

In 1879 Mr. Herreshoff and his brother incorporated the Herreshoff Manufacturing Company, of which he was president and treasurer from its formation to the time of his death.

In 1892 the Herreshoff Manufacturing Company took up the designing and construction of yachts, with special reference to building craft that would enable the New York Yacht Club to hold the trophy against attack. The record of the Vigilant, Defender, Columbia, Reliance and Resolute indicate to what height of perfection Mr. Herreshoff's firm has carried the science of naval designing and construction.

Mr. Herreshoff was a member of the Institute of Naval Architects of London and a member of this Society since its organization. He died on July 20, 1915.

ALBERT LLOYD HOPKINS

Albert Lloyd Hopkins, the son of Stephen DeForest and Elizabeth G. Hopkins, was born on September 7, 1871, at Glens Falls, N. Y. His early life was passed in that city and in Troy, N. Y., and there his early education was received. He died May 7, 1915, at the time of the Lusitania disaster.

In 1888 he entered Rensselaer Polytechnic Institute for the course in civil engineering. He was graduated in 1892 with high honors, and in later years the Director of the Institute said of him:—"About 10 per cent of those who apply are admitted to the Institute, about 20 per cent of those admitted are graduated, and among these once in a while we find a Hopkins."

After a few months' work in an architect's office in Chicago, in the summer of 1892, Mr. Hopkins was appointed to a position in the Bureau of Construction and Repair of the Navy Department, at Washington, D. C.,

which position he held for about eighteen months, being sent to Newport News, Va., in February, 1894, as a member of the staff of Naval Constructor J. J. Woodward, U. S. N., the first superintending constructor assigned to duty at the works of the Newport News Shipbuilding and Dry Dock Company.

In the summer of 1897 Mr. Hopkins was transferred from Naval Constructor Woodward's office and assigned to the Graduate School of Naval Architecture at the U. S. Naval Academy, Annapolis, Md., at which place he was an instructor and lecturer on naval architecture and ship construction.

At the outbreak of the Spanish War in April, 1898, the officers and students of the academy joined the fleet, and Mr. Hopkins was assigned to the naval station at Key West, Fla., the nearest station to the blockading fleet operating in Cuban waters. While at Key West he was in charge of all the "construction and repair" work done for the fleet at that station. He was also active in improving the efficiency of the plant, installing much new equipment and increasing its capacity as a repair station for naval purposes.

It was while engaged in the work at Key West that Mr. Hopkins received from the late W. A. Post, Member American Society of Civil Engineers, then general superintendent of the shipyard, an offer to return to Newport News and enter the service of the Newport News Shipbuilding and Dry Dock Company. He accepted, and in August, 1898, returned to Newport News as the personal assistant of Mr. Post.

The able constructive work done by Mr. Hopkins in the years following will always be remembered by those who were associated with him. Gifted with a rarely keen mind, he was quick to grasp the essentials of any situation. His education and training qualified him to choose unerringly the right course to pursue, and his strong will and personality enabled him to carry to its logical conclusion the course so chosen. United with these strong characteristics were an unfailing courtesy and a consideration for others, which endeared him to all his associates.

In 1905, when Mr. Post was made general manager of the company, Mr. Hopkins was appointed assistant general manager, and, in 1911, when Mr. Post succeeded to the presidency, on account of the death of Mr. C. B. Orcutt, Mr. Hopkins was made manager.

On the death of Mr. Post in February, 1912, Mr. Hopkins was elected vice-president, and became the chief executive officer of the company, with headquarters in New York City. In this new field he fully sustained the high position accorded to his predecessors, and it was quickly and widely recognized that an able executive was directing the company's affairs. In his own profession, and also among the men whom, because of his profes-

sion, he was called on to meet—bankers, lawyers, and men of large business affairs—his influence was deep and ever increasing. His election as president of the company in March, 1914, was recognized as a well-earned tribute to his ability and his devotion to the interests committed to his care.

Loyal to his friends and associates, loyal to those who trusted their interests to him, loyal always to his own high ideals, well and truly does he deserve the tribute expressed in the following telegram sent by Mr. Huntington to the company:—

"Mrs. Huntington and I are distressed beyond expression at the death of Mr. Hopkins. We believe the company and all the employees share our sorrow and will mourn the loss of a splendid officer and a noble man."

To those who knew him best, to his friends and associates of many years, the tidings of the Lusitania disaster brought a sure message—well they knew that the gentle, kindly courtesy, the ever-present, instinctive disposition to serve others before considering himself, would unfailingly include him among those who died that others might live.

In June, 1906, Mr. Hopkins was married to Miss May Davies, of Chase City, Va., who, with their daughter, May Davies Hopkins, survives him. He is also survived by his mother, of Glens Falls, N. Y., and his brother, Charles E. Hopkins, of Hudson, N. Y.

He was a member of Council of this Society, a member of the American Society of Naval Engineers, the American Academy of Political and Social Science, and an associate member of the American Society of Civil Engineers.

CONSTANTINE JANSSON

LEOPOLD KATZENSTEIN

Leopold Katzenstein, a member of the Society since 1893, was born July 23, 1843, in Hesse-Cassel, Germany, and died in New York City on

December 3, 1915. He received his schooling in Germany, followed by some years of invaluable practical training and experience.

In 1869 he came to the United States, and with characteristic energy immediately developed ideas which the wider field of this country afforded.

He was among the first to realize that steam machinery was to use higher pressures, and his first patents were issued to cover what are today known throughout the world as Katzenstein's Metallic Packings. He was the recognized pioneer and leader in this field and patented a large number of devices covering improvements in this art. Other patents held by him covered automatically operated bulkhead or compartment doors for ships or mines, lifeboat appliances, etc. He also built up an extensive business for the manufacture and repair of machinery.

He was a member of this Society, the American Society of Naval Engineers, the Railroad Club, the Technischer Verein, and of many charitable organizations.

In a long and honorable business career he established an enviable reputation for integrity and ability, and his lovable personality brought him a host of friends.

He was of a modest and retiring disposition. He was a high-minded citizen. In charity without display he gave generously to the needy. His faith in God was steadfast, and as a husband and father he was gentle and noble.

JOHN LOYD

John Loyd was born in Newton, Mass. He was educated in the public schools, followed engineering and entered the Navy at the outbreak of the Civil War, serving in the engineering department of several vessels, was commended for efficiency and honorably discharged at the end of the war. Shortly afterwards he started in business in New York, manufacturing small machinery parts, in which business he was engaged at the time of his death.

ALEXANDER JAMES MACLEAN

Prof. Alexander J. Maclean, who died in this city December 19, 1914, was born April 2, 1861, at Sheerness-on-Sea, England, where he received

his early education and served a seven years' apprenticeship at H. M. Dock Yard School. Later he secured a position as chief draughtsman with shipbuilding concerns at Belfast, Ireland, and Newcastle-on-Tyne, England. In 1889 he came to the United States, becoming a citizen thereof in 1894, and secured employment for a short time with the Government at the Norfolk navy yard. Thence he went to William Cramp & Sons Ship and Engine Building Company, Philadelphia, where he was employed for about five years.

In September, 1896, he went to Webb's Academy, Fordham Heights, New York City, as professor of naval architecture, a position which he held until his death. His technical education and practical experience acquired in the land of his birth made him a man peculiarly fitted for the position. While holding this position he conducted for several years a night class in naval architecture at Franklin Institute, Philadelphia, of which he was a member, and also another night class at Cooper Union in this city. He took great pride in his profession, and because of his large experience was frequently called upon to give expert testimony in admiralty cases.

Together with J. W. Millard he designed and had built in 1906 for New York City the ferryboats which were named after the five different boroughs. He also designed and had built for the city of St. John the ferryboat Ludlow, the first steel boat built in New Brunswick.

HARRISON BRAY MOORE

Harrison B. Moore was born in Windham, Me., in 1842, and was educated in the public schools of that town. He made his home in New York in 1858 and in 1863 started in the lighterage business. When the New York Lighterage and Transportation Company was incorporated in 1874, he became its president and maintained active connection with the company until 1905, when he retired from business. He was also a director of the Lake George Real Estate Company and of the Theodore A. Crane's Sons Company.

Mr. Moore was an enthusiastic yachtsman all his lifetime. He was a member of the New York Yacht Club, the Larchmont Yacht Club, the Lake George Yacht Club, the Atlantic Yacht Club and the Biscayne Yacht Club of Miami. He was the owner of the motor yacht Naya, at various times owned other large yachts, including the Marietta, built for his wife, and the Onontino, the first 35-mile-an-hour motor boat, built in 1905.

Mr. Moore was connected for many years with several railroad companies with the late Collis P. Huntington. When he retired from business he sold his water transportation interests to the Lehigh Valley Railroad Company. His lighterage boats handled all the iron and steel for the construction of the Brooklyn Bridge and the Brooklyn Elevated Railroad.

Mr. Moore was for years prominently identified with the National Guard of New York State, having been in 1879 Quartermaster of the Eleventh Brigade, with the rank of major, and in 1884 ordnance officer of the Third Brigade with the same rank.

He died on March 4, 1915.

REVERE BURHAM PULSIFER

Mr. Pulsifer was born at Manchester-by-the-Sea, Mass., on July 17, 1889, and was a graduate of the Massachusetts Institute of Technology, Class of 1912, Course XIII, Naval Architecture, and after graduation continued there as an assistant instructor for one year. Later he was employed by the Newport News Shipbuilding and Dry Dock Company, and at the time of his death he was connected with the design and scientific section of the Lake Torpedo Boat Company. He was a junior member of this Society. He died on September 29, 1915.

FREDERICK GORAHL ROGERS

Frederick Gorahl Rogers was born in Bowling Green, Ohio, August 22, 1857, and died December 1, 1914. He attended the public schools of Toledo, Ohio, and later Jorden's College, and entered the machinist's trade, subsequently serving in the engineer's department of various harbor craft and rising to the position of chief engineer of the steamers Macon and Oceanic. In 1894 he was appointed chief engineer of the Lehigh Valley Company's fleet and subsequently became superintendent.

EDWARD SMITH

MAJOR GENERAL D. S. VASSILIEFF

Dimitri Stepanovitch Vassilieff, major-general, Imperial Russian Navy, was born on February 10, 1871; received his education in the Naval Academy (Morskoi Korpus) in Petrograd, and graduated in 1891 with the rank of ensign. The first years of his service he spent on board different ships of the Imperial Russian Navy, first as watch officer and afterward as watch lieutenant. In 1899 he was appointed to the post of paymaster (in the Russian Navy there is no special branch for this service, and the positions of paymasters are filled by executive officers) on board the cruiser Varyag, then under construction at the William Cramp & Sons yards in Philadelphia, Pa., and remained on board this ship till the Varyag left the shipbuilding yard. This was the first time he came to the States, and during his long stay in Philadelphia he became familiar with the English language.

After the Varyag was completed Vassilieff remained on board that ship till 1903. In 1906 he was appointed to the post of commander (first executive officer) of the battleship Andrey Pervozvanny. He remained on the post only a short time and in the same year was appointed aide-de-camp to the Assistant Minister of the Navy, Rear-Admiral Bostroem, and in 1907 accompanied him on board the imperial yacht Standart when his Majesty, the Emperor of Russia, went to Swinemuende to pay a visit to the Emperor of Germany.

In 1909, while commander of the Imperial Russian Navy, he was appointed naval attaché to the Russian Embassy in Washington, and shortly afterward, in 1911, was promoted to the rank of captain of the Imperial Russian Navy for distinguished services rendered to the navy.

When the war began Captain Vassilieff was in Russia on leave, but immediately returned to his post in Washington and took charge of the orders that had to be placed in the States on behalf of the Russian Navy.

A painful disease carried him away in the midst of his activity, and he died in the spring of 1915, promoted to the rank of major-general a few days before his death.

CHARLES WARD

Charles Ward was born in Leamington, England, March 5, 1841, and came to America in 1871. He had been trained as a gas engineer in England and almost his first work in America was in Charleston, W. Va., where he installed the first gas works and later became the superintendent and general manager of the company. From this time Charleston became his home.

Outside of local prominence in western river steamboating, Mr. Ward attracted the special attention of the engineers of the country when the late Admiral Melville invited the makers of water-tube boilers to compete for supplying the boilers for the coast-defense vessel Monterey. Mr. Ward's boiler was tested in 1890 and was noteworthy for the length of the test under severe conditions and the excellent efficiency attained. As a result four boilers of this type were installed on the Monterey, and he thus has the credit of the first installation of water-tube boilers on a large war vessel.

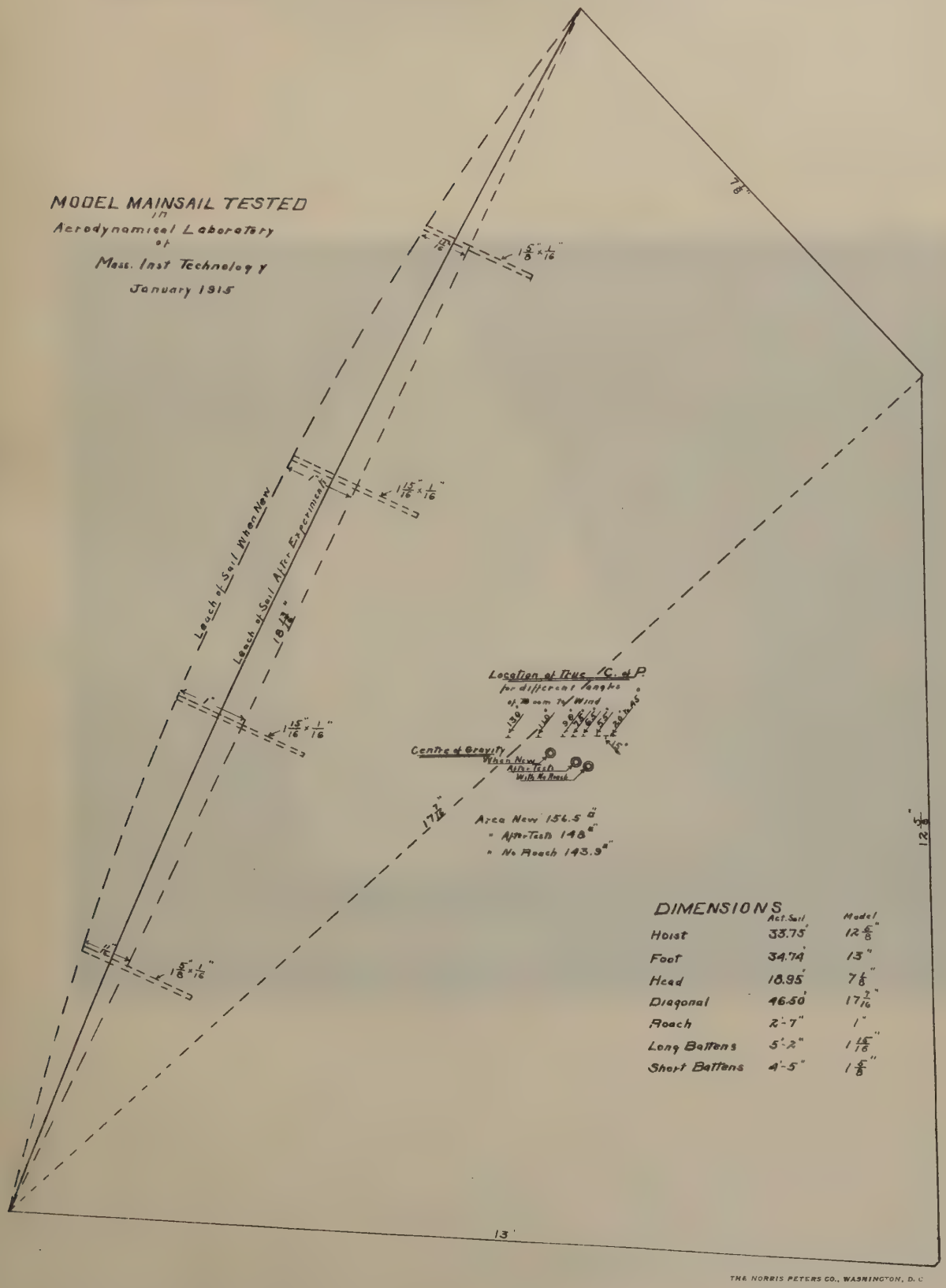
Even before this, smaller water-tube boilers of a different design manufactured by Mr. Ward had been used in steam launches of the United States Navy, and they have given such satisfaction that the Navy Department has continued their purchase and use up to the present time.

Mr. Ward was also a pioneer in the use of screw propellers on western river steamboats in the effort to reduce waste and increase efficiency as compared with the time-honored stern-wheel boats, which are almost exclusively in use. Some years ago Mr. Ward carried out a repetition of the famous test in England, during the first half of the last century, of a tug of war between a screw-propelled boat and a stern-wheel boat of the same power. In the later case, as in the earlier one, the screw propeller showed the better results.

Mr. Ward was a man of agreeable personality, who inspired confidence and respect in all who were associated with him. He occasionally contributed papers to the engineering societies, but, as so often happens, the man of deeds was not the man of words, so that his contribution to marine engineering was in the courageous development of new ideas rather than in the clever telling of what had been done by himself or others. His business, which was at first carried out in his own name, later became the Charles Ward Engineering Works. He died January 17, 1915.

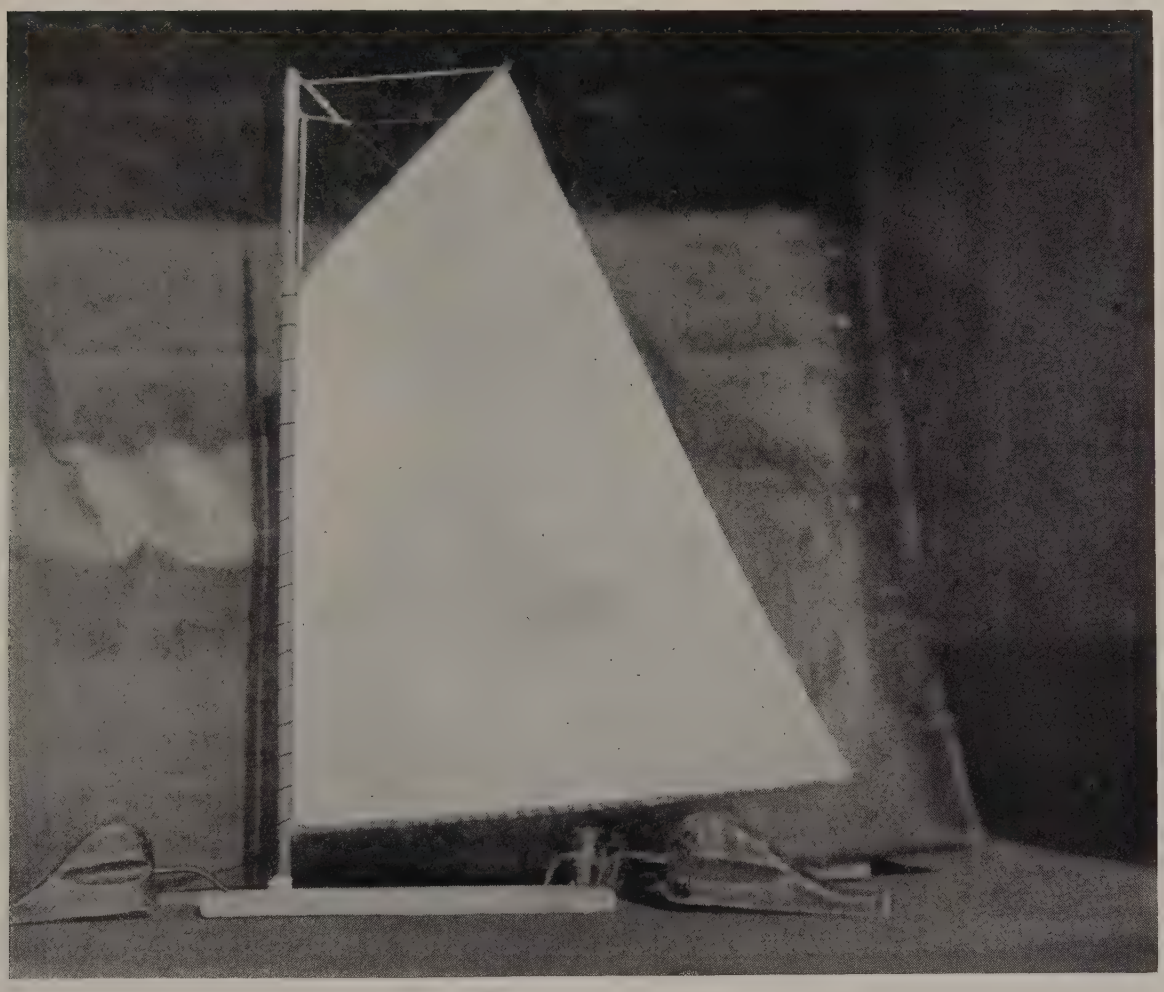
PLATES

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.

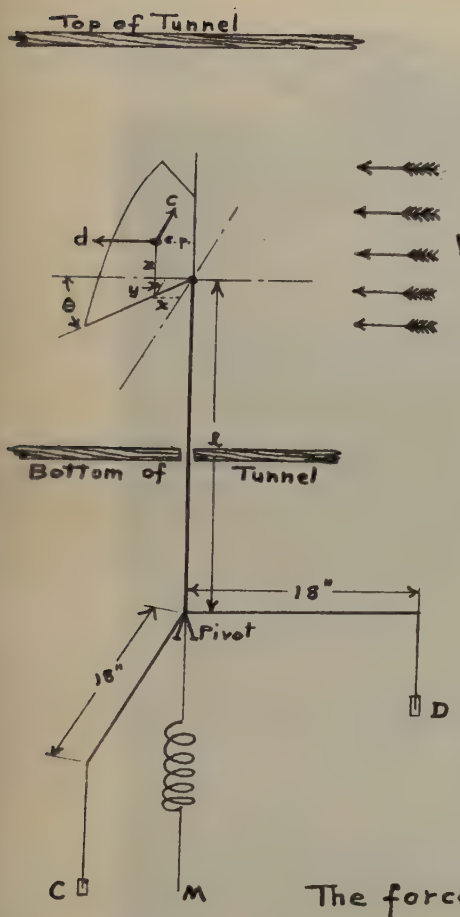


PHOTOGRAPH OF SAIL.

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.

General View of Aerodynamical Laboratory at Massachusetts Institute of Technology.

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail, by Professor H. A. Everett, Member.

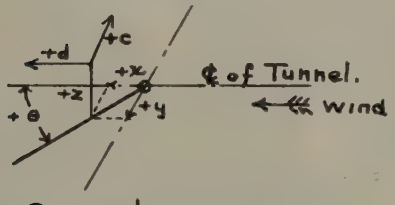


C - Weight in Scale Pan of Transverse Arm.
D - Weight in Scale Pan of Longitudinal Arm.
M - Moment of Sail about Mast.
c - Transverse Component of Force on Sail.
d - Longitudinal Component of Force on Sail.
θ - Angle of Boom to Wind.
x - Coördinate of Center of Pressure along Line of Wind.
y - Coördinate of Center of Pressure across Line of Wind.
z - Height of Center of Pressure above Top of Boom at Mast.
ℓ - Height of Bot. of Boom at Mast above pivot.
$\ell_1 = 30.45$ inches, $\ell_2 = 24.05$ inches.

c, d, x, y, z, are unknown quantities to be computed.

The forces acting on the sail are referred to the plane of the boom and mast.

SIGNS



+θ as shown.
+x down stream.
+y as shown.
+z upwards.
+c as shown.
+d down stream.

Equations for Solution of c, d, x, y, z.

(1) $36\,C_1 = c(\ell_1 + z)$.

(2) $36\,C_2 = c(\ell_2 + z)$.

(3) $36\,D_1 = d(\ell_1 + z)$.

(4) $36\,D_2 = d(\ell_2 + z)$.

(5) $M = cx + dy$.

(6) $\tan\theta = \frac{y}{x}$.

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C - Weight in Scale Pan of Transverse Arm

d - Longitudinal Component of Force on Sail.

x - Coordinate of Center of Pressure along Line of Wind.

y - Coordinate of Center of Pressure across Line of Wind

z - Height of Center of Pressure above Top of Boom at Mast.

l - Height of Bot of Boom at Mast above pivot.

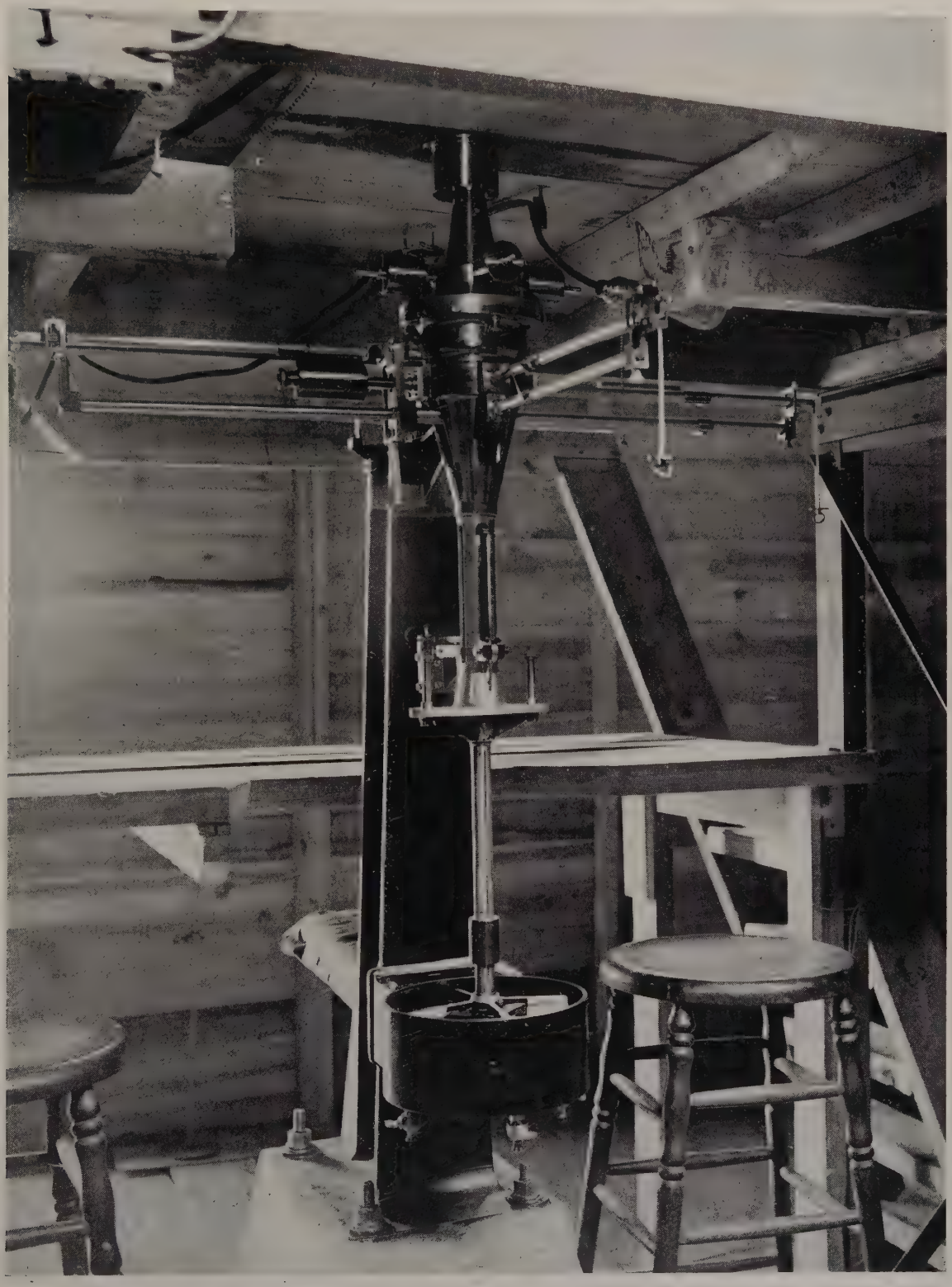
l_1 = 30.45 inches; l_2 = 24.05 inches.

c, d, x, y, z, are unknown quantities to be computed.

on the sail are referred to the the boom and mast.

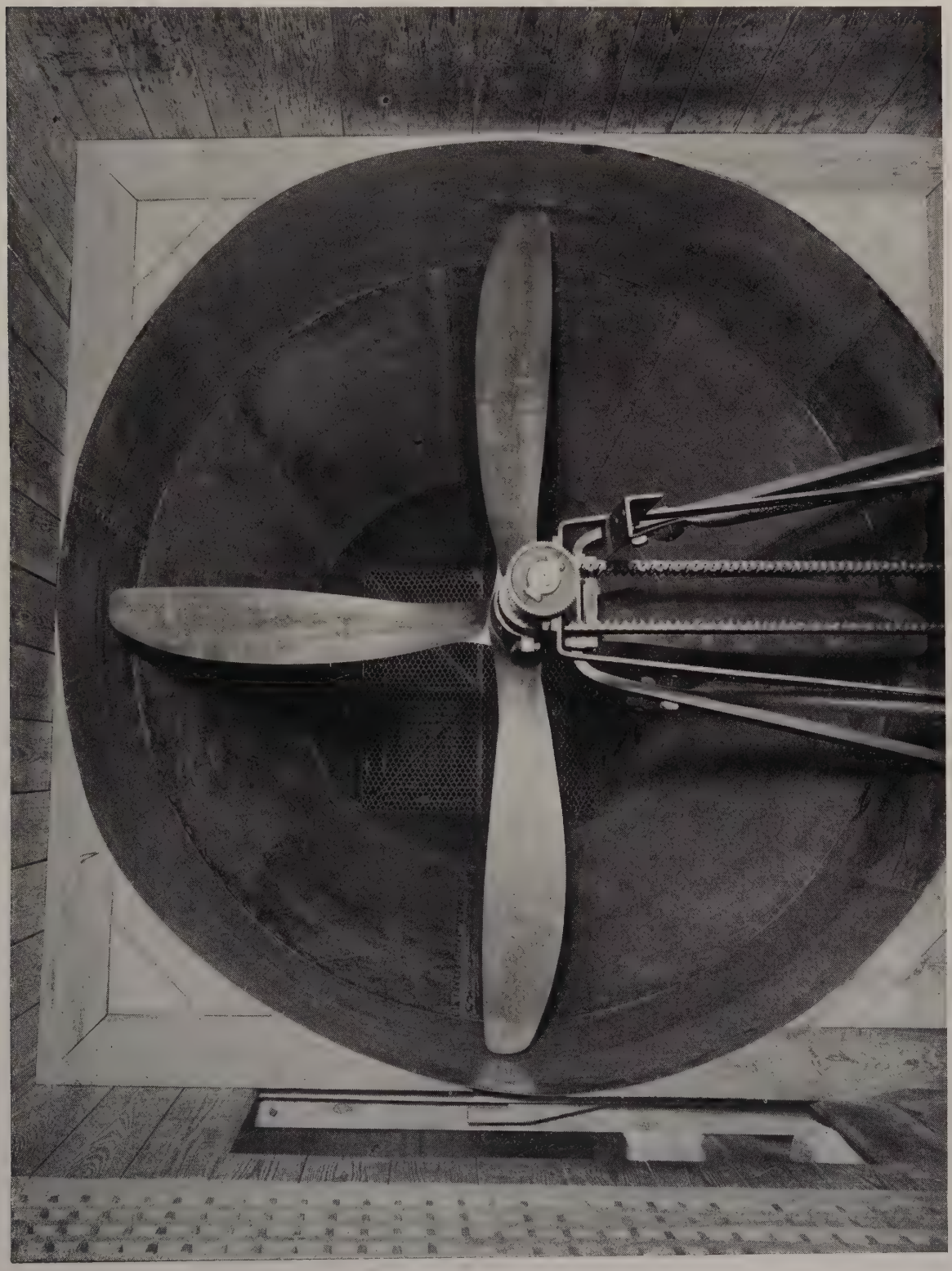
Solution of c, d, x, y, z.

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.



Aerodynamical Balance in Position Below Floor of Tunnel. The Vertical Shaft Projects Up Through Floor of Tunnel and Carries Model.

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.



Seven-Foot Suction Propeller Viewed from Discharge Chamber. The Equalizing Vanes and Tubes May be Seen at the Further End (Entrance) of the Tunnel

To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.

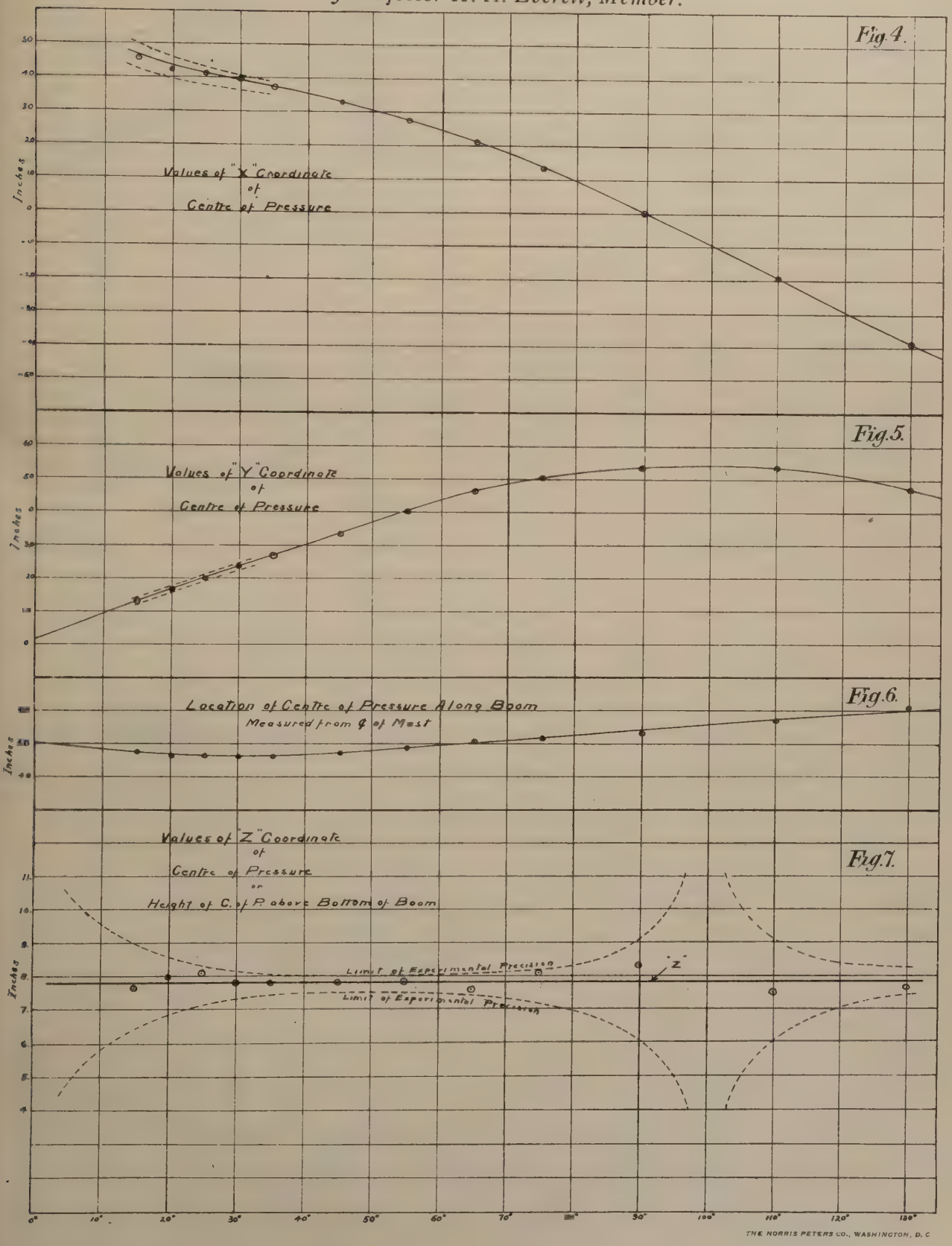


Fig.4.
Values of "X" Coordinate of Centre of Pressure
Inches
Fig.5.
Values of "Y" Coordinate of Centre of Pressure
Inches
Fig.6.
Location of Centre of Pressure Along Boom
Measured from ℄ of Mast
Inches
Fig.7.
Values of "Z" Coordinate of Centre of Pressure or Height of C. of P. above Bottom of Boom
Inches
Limit of Experimental Precision
Limit of Experimental Precision
Z
0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130°

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To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.

Fig.4.

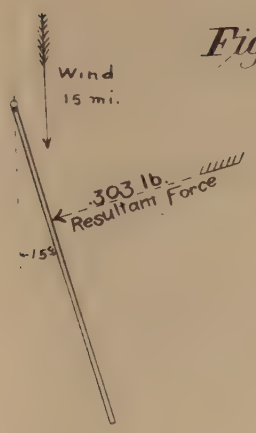


Fig.5.

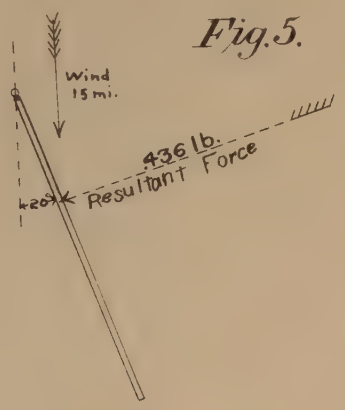


Fig.6.

Fig.7.

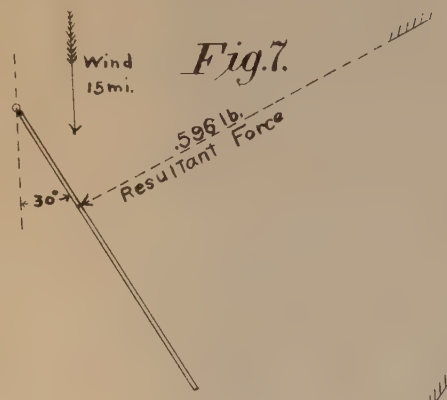


Fig.8.

Fig.9.

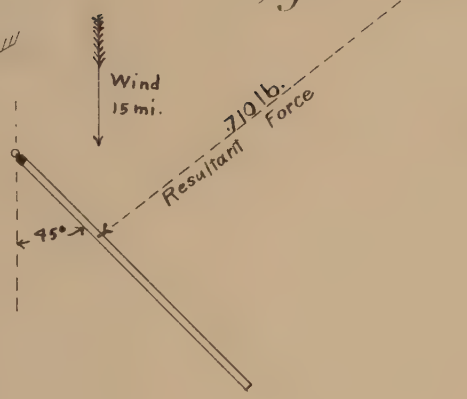


Fig.10.

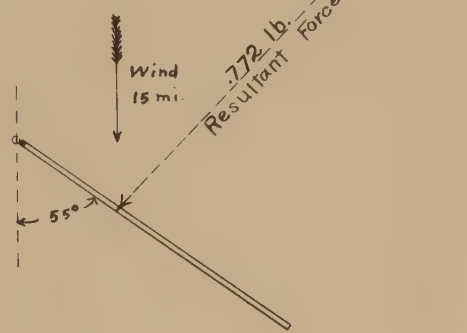


Fig.11.

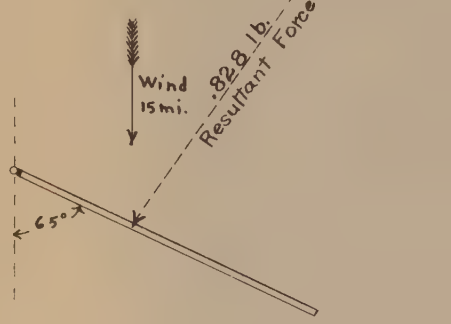


Fig.12.

Fig.13.

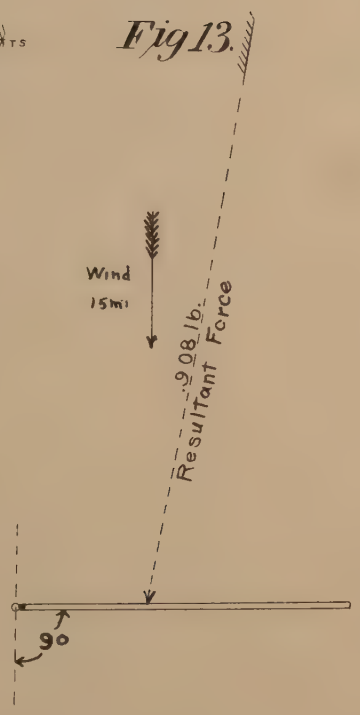


Fig.14.

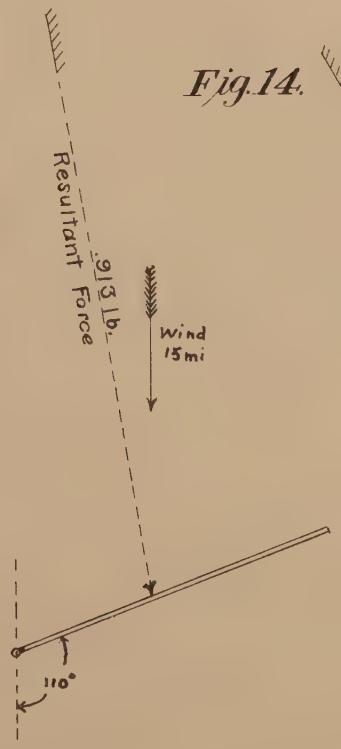
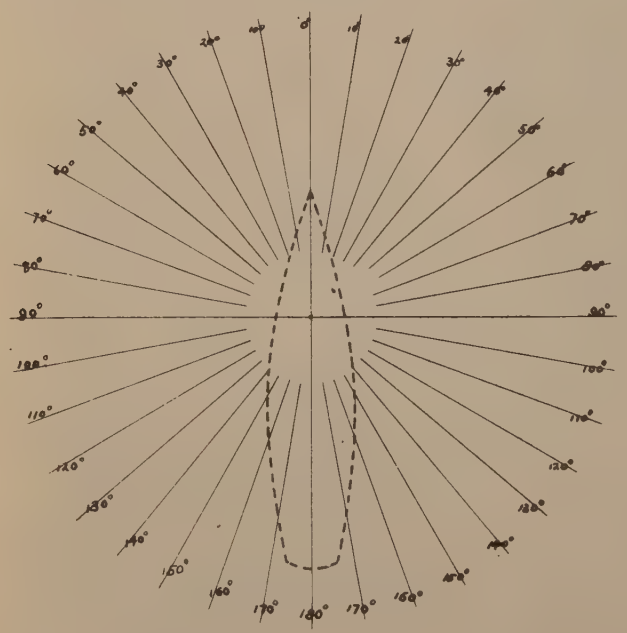


Fig.15.

Fig. 16.



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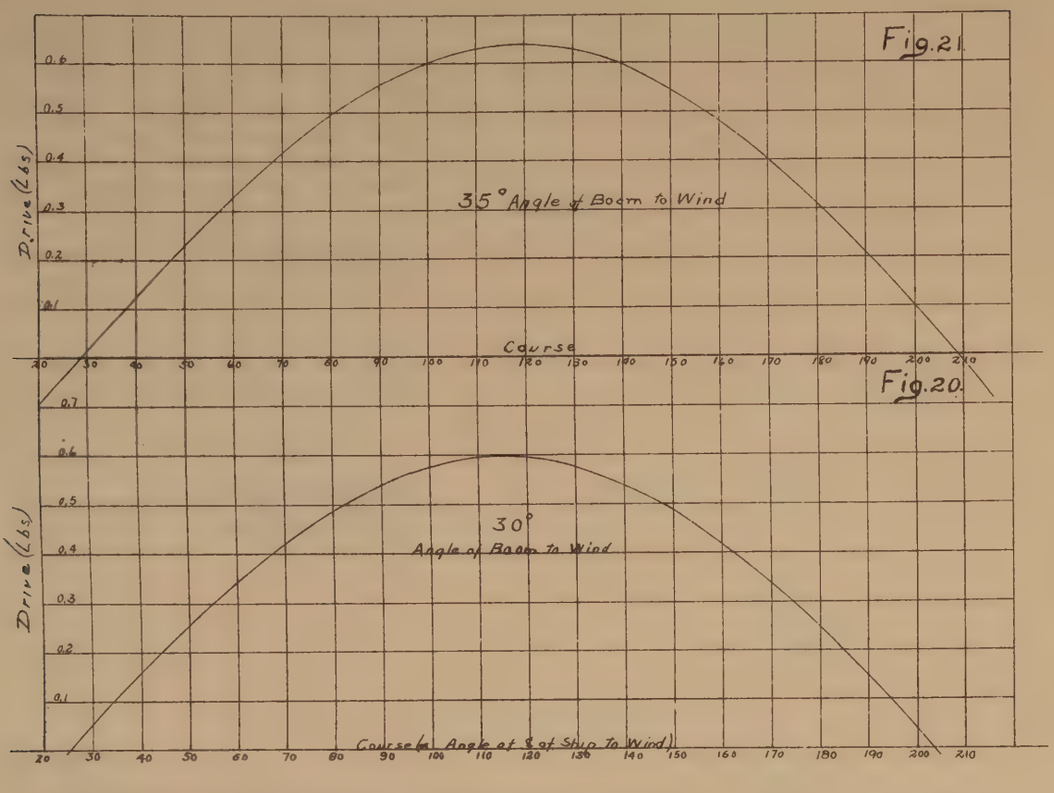


Fig.21.
35° Angle of Boom to Wind
Drive (Lbs.)
Course
Fig.20.
30°
Angle of Boom to Wind
Drive (Lbs.)
Course (or Angle of ℄ of Ship to Wind)

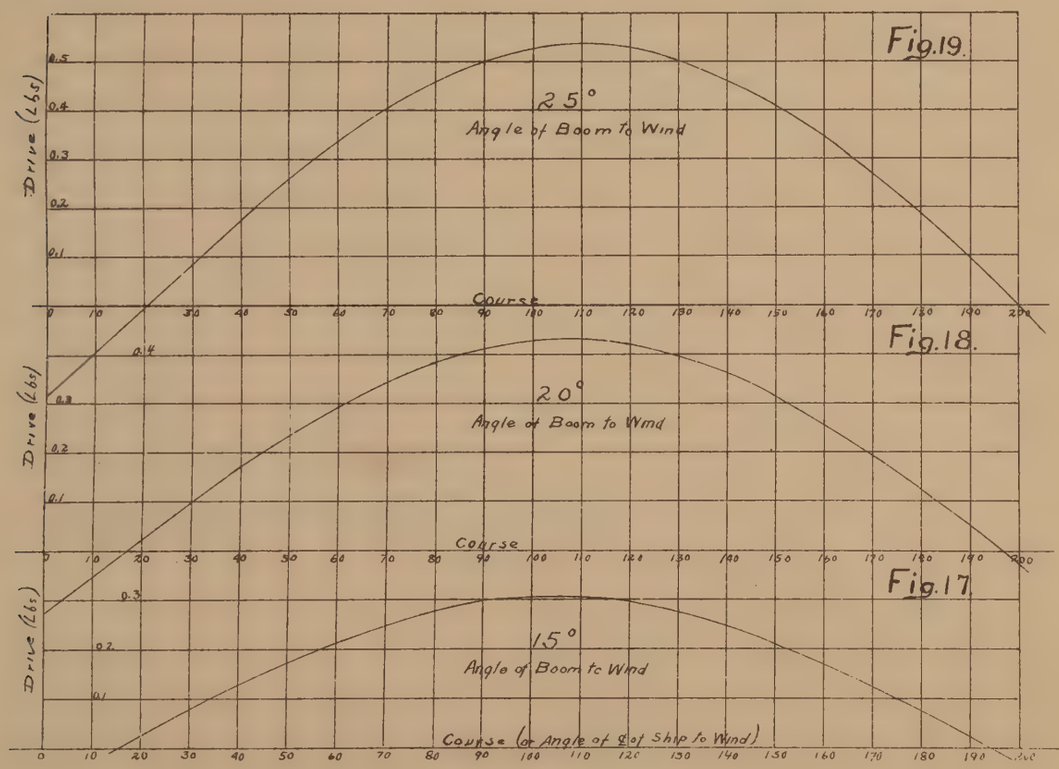


Fig.19.
25°
Angle of Boom to Wind
Drive (Lbs.)
Course
Fig.18.
20°
Angle of Boom to Wind
Drive (Lbs.)
Course
Fig.17.
15°
Angle of Boom to Wind
Drive (Lbs.)
Course (or Angle of ℄ of Ship to Wind)

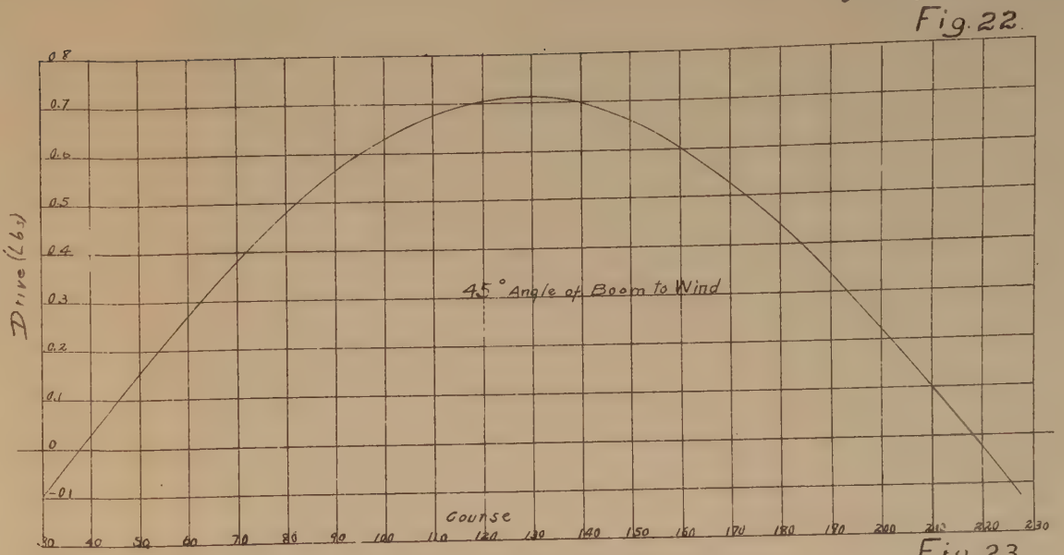


Fig.22.
45° Angle of Boom to Wind
Drive (Lbs.)
Course

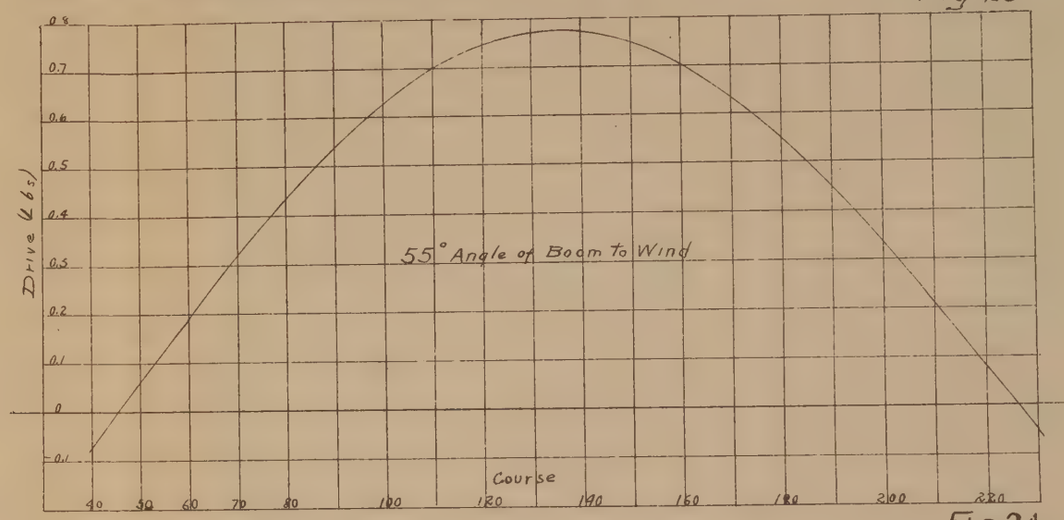


Fig 23
55° Angle of Boom to Wind
Drive (Lbs.)
Course

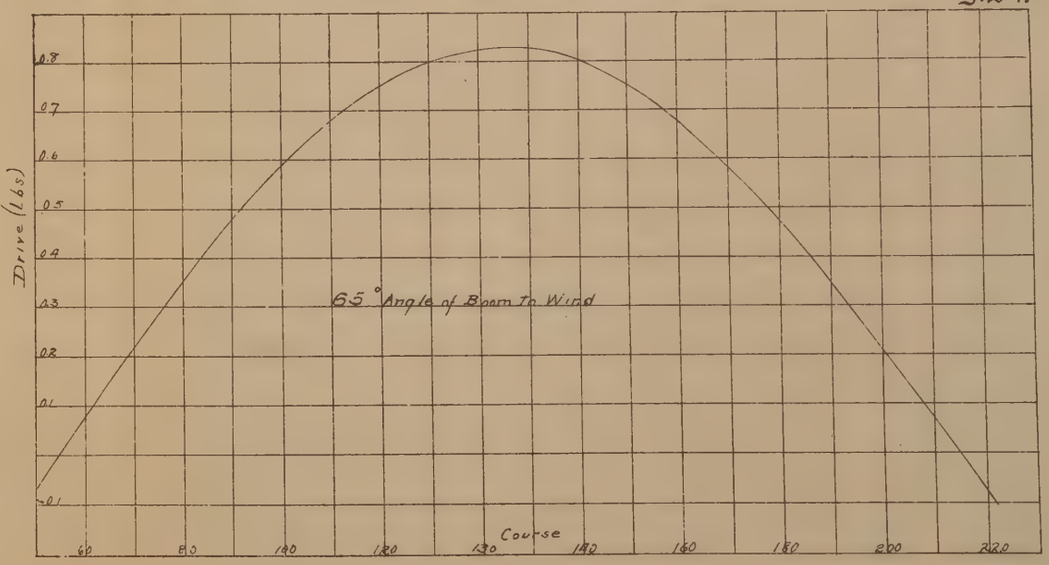
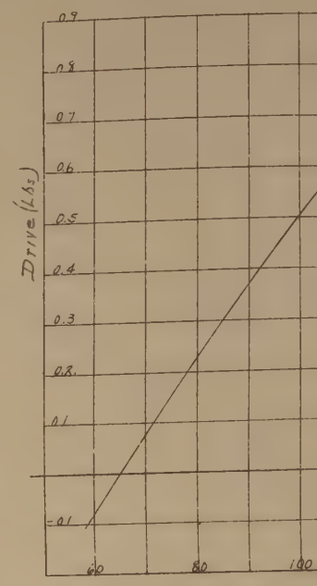


Fig.24.
65° Angle of Boom to Wind
Drive (Lbs.)
Course


Drive (Lbs.)

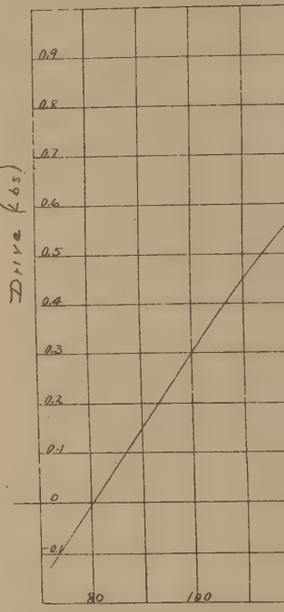

Drive (Lbs.)

Fig.25

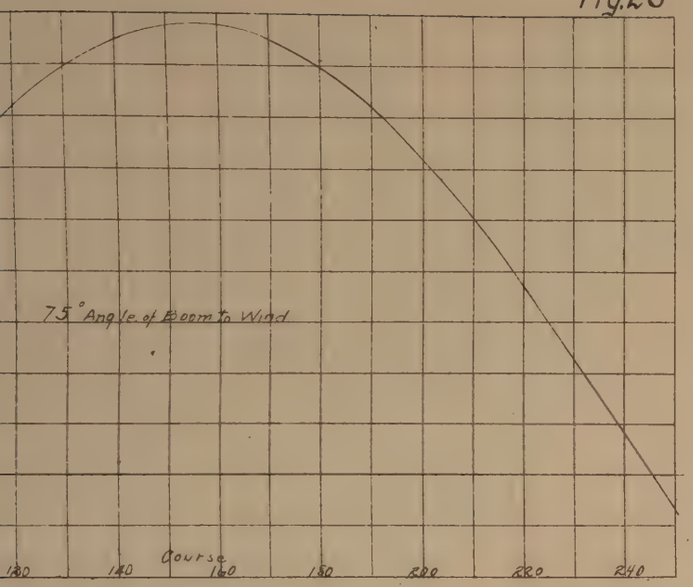


Fig 26

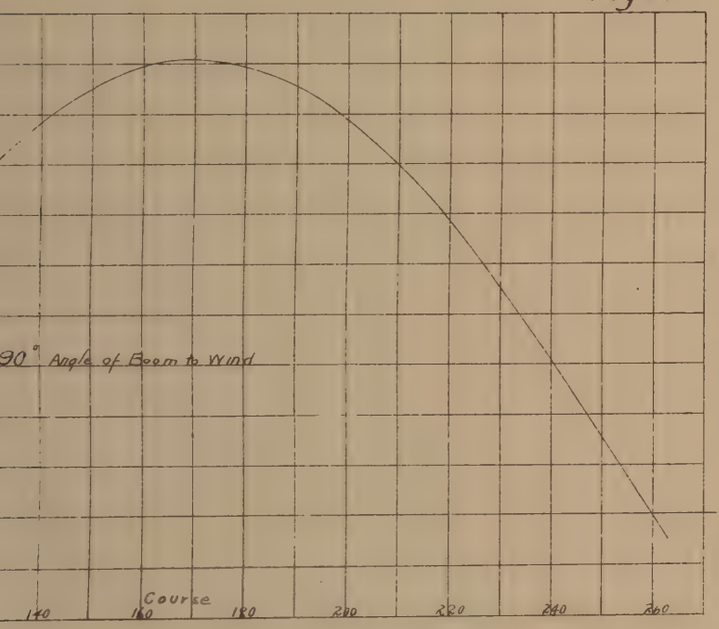


Fig 27

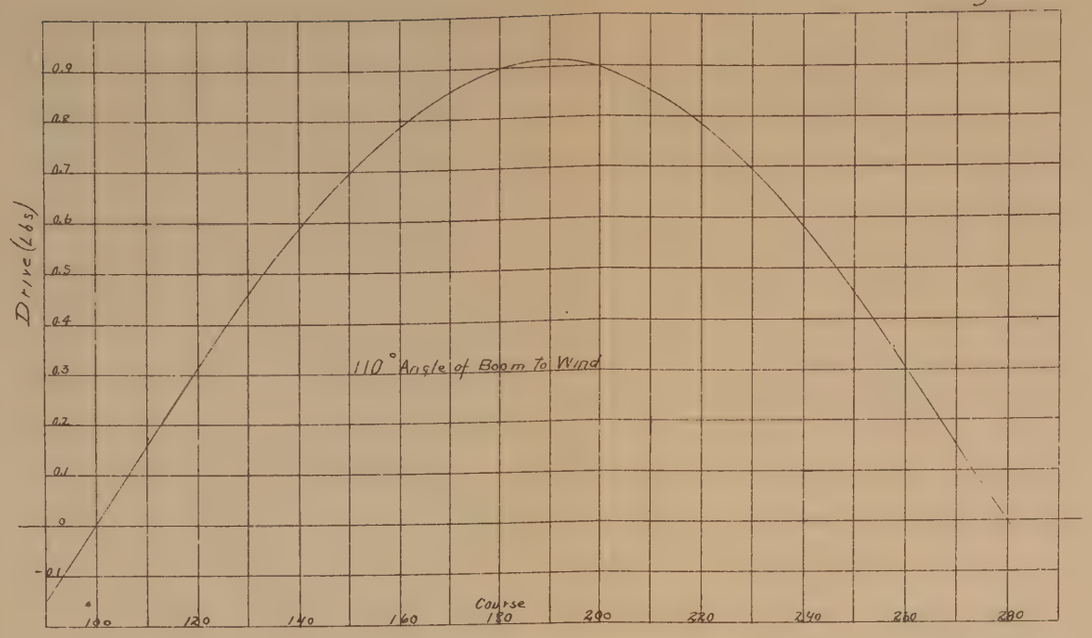
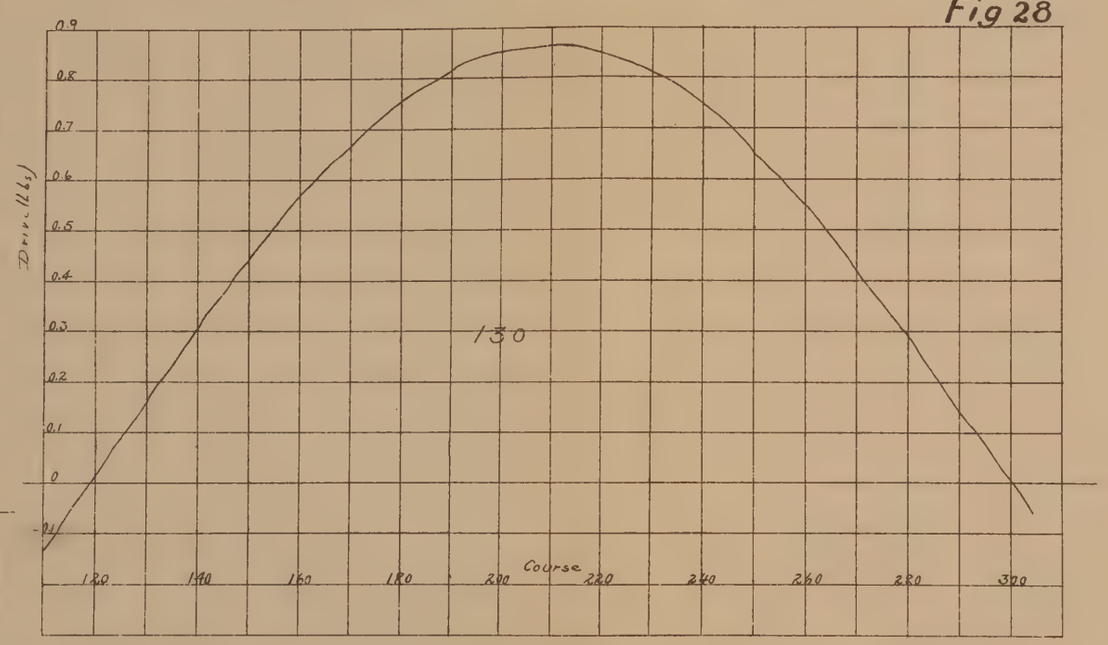


Fig 28



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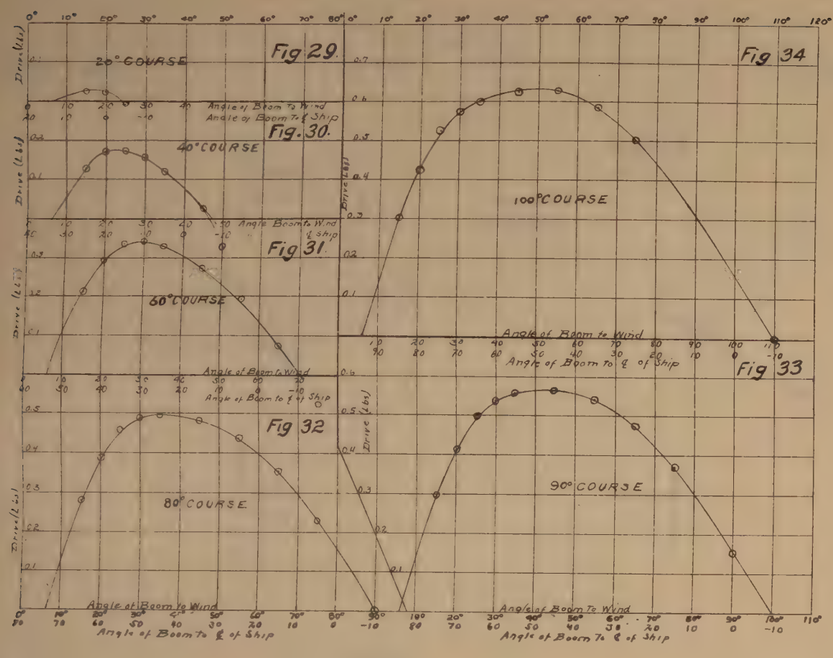
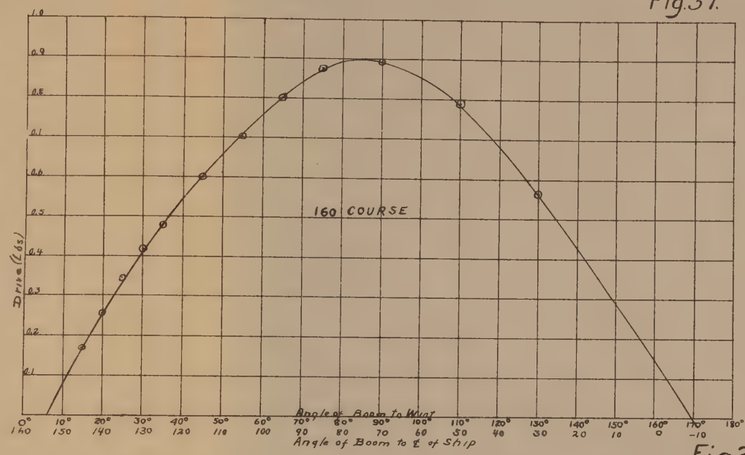
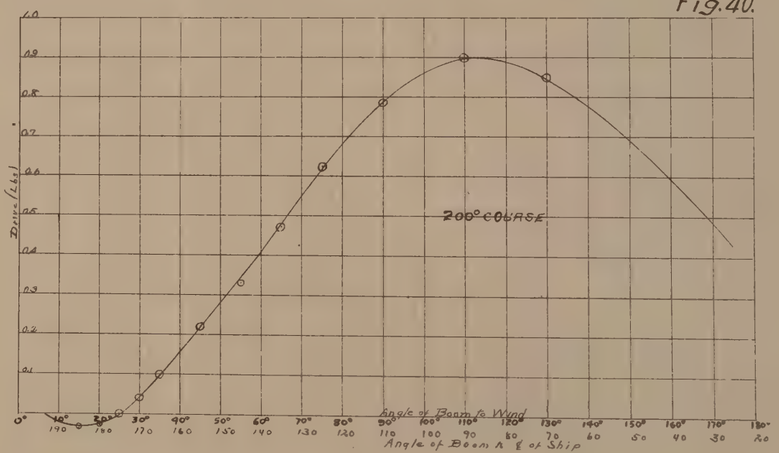
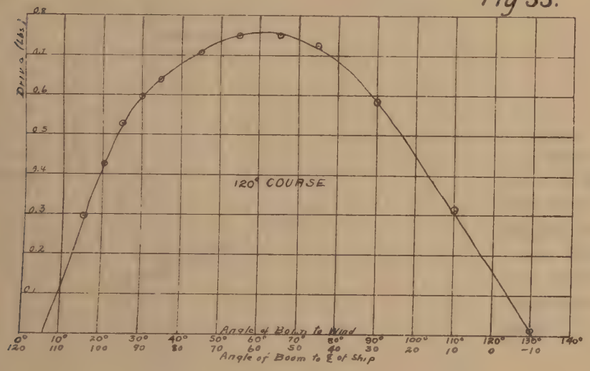
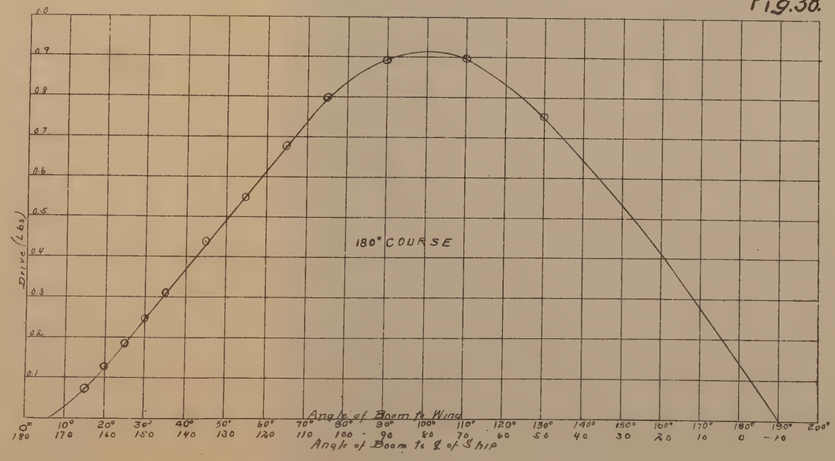
To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.











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To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail."
by Professor H. A. Everett, Member.

Fig. 41

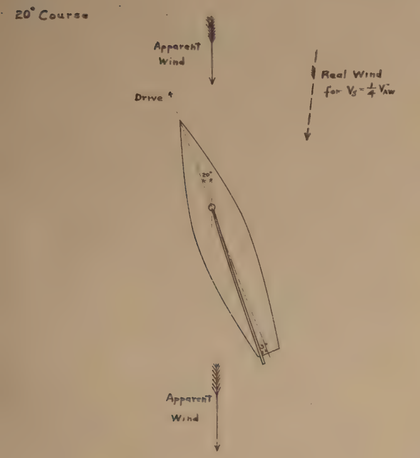


Fig. 42

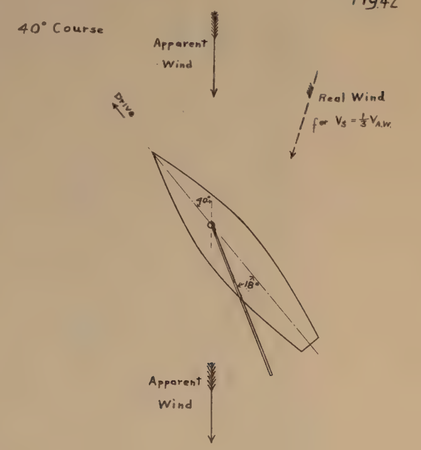


Fig. 43

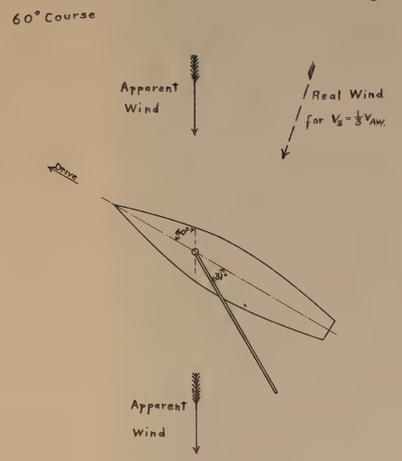


Fig. 44

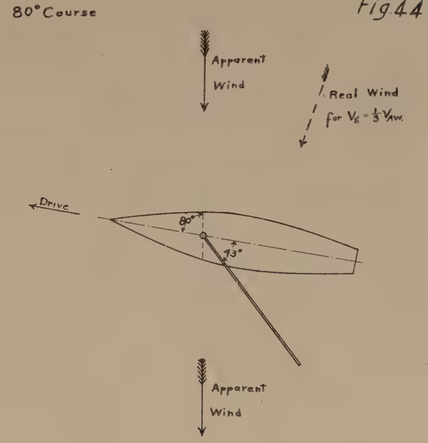


Fig. 45.

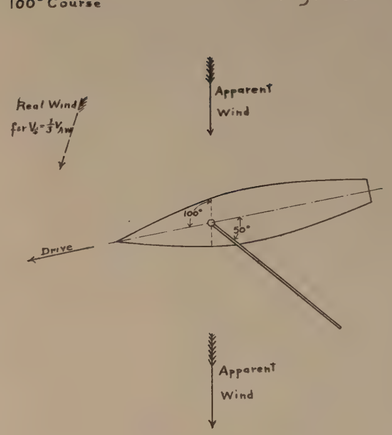


Fig. 46.

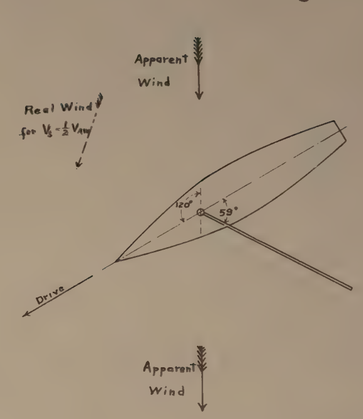


Fig. 47.

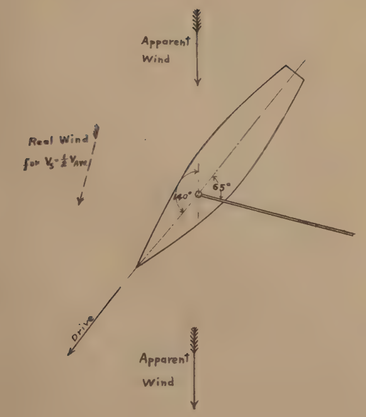


Fig. 48.

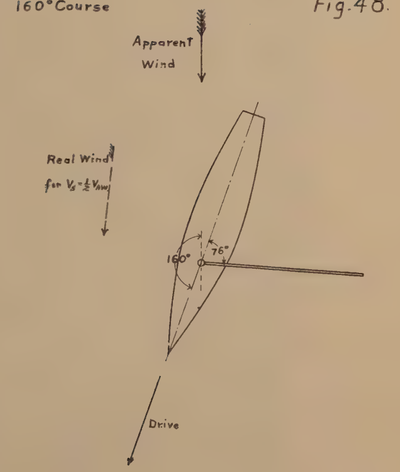


Fig. 49.

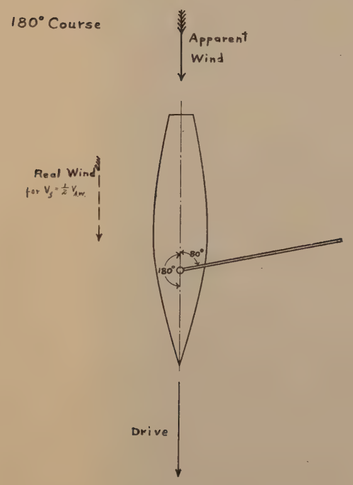


Fig. 50.

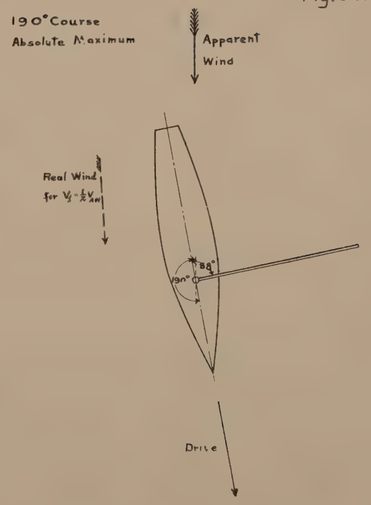
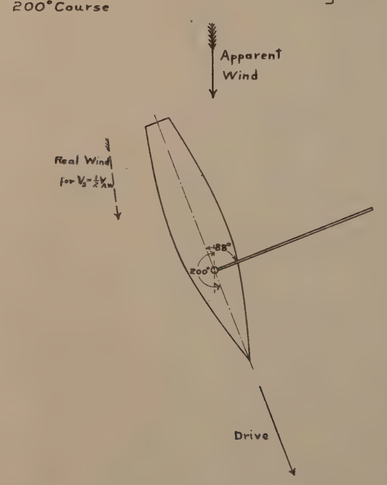


Fig. 51.



Note:
In these figs. the Arrows showing wind indicate Direction Only.
Those showing Drive indicate Direction and Amount.

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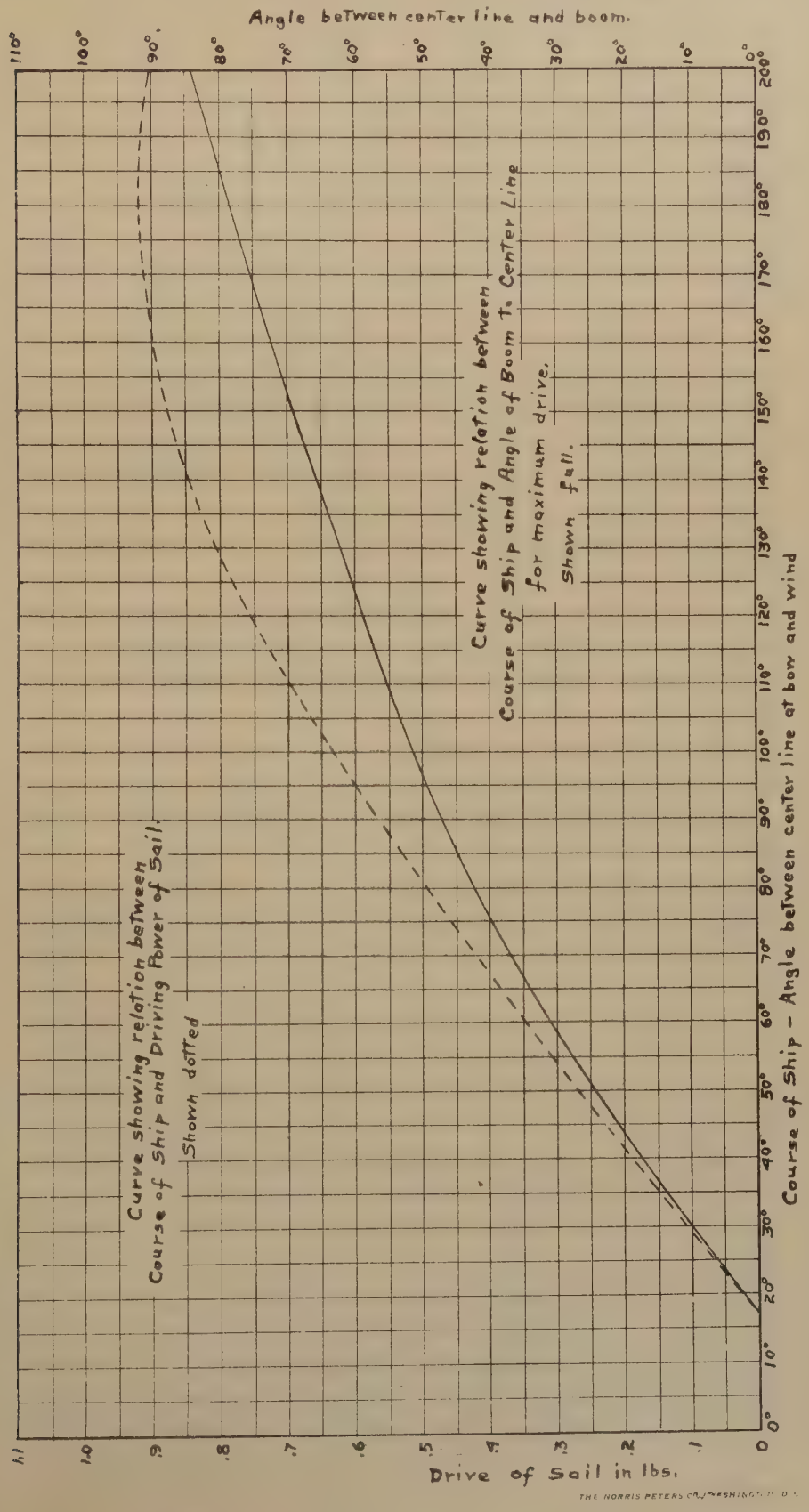
To illustrate paper on "Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.


Angle between center line and boom.
110° 100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0°
200° 190° 180° 170° 160° 150° 140° 130° 120° 110° 100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0°
Curve showing relation between Course of Ship and Angle of Boom to Center Line for maximum drive. Shown full.
Curve showing relation between Course of Ship and Driving Power of Sail. Shown dotted
Course of Ship - Angle between center line of bow and wind
1.1 1.0 .9 .8 .7 .6 .5 .4 .3 .2 .1 0
Drive of Sail in lbs.

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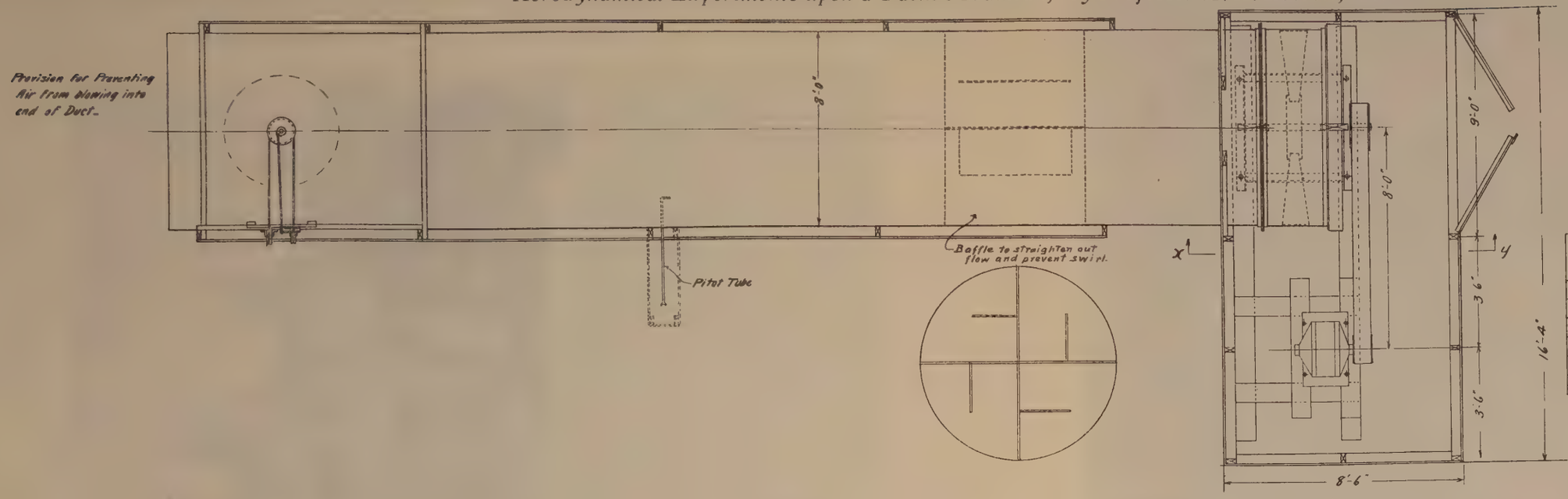
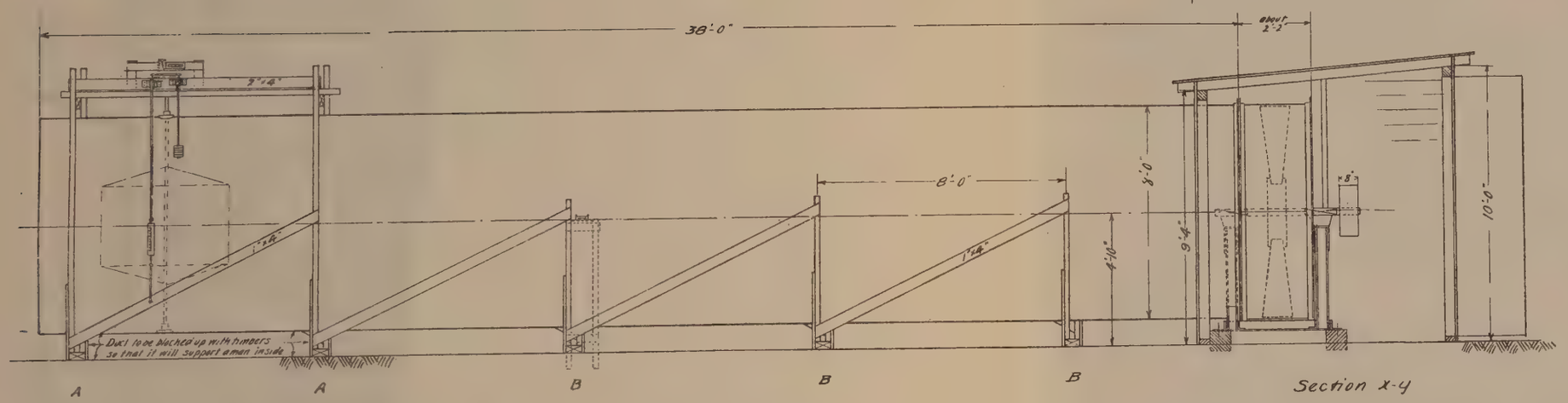
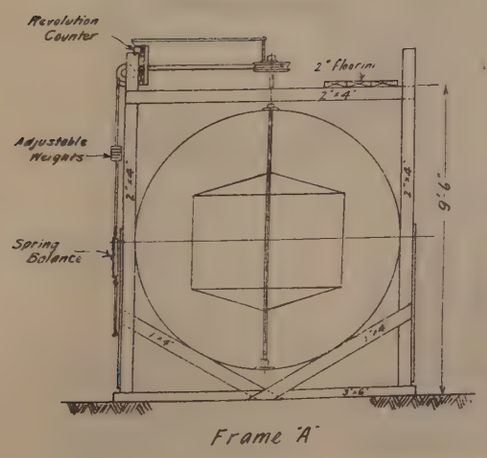
To illustrate discussion by H. DeB. Parsons, Esq., on paper entitled
"Aerodynamical Experiments upon a Yacht's Mainsail," by Professor H. A. Everett, Member.

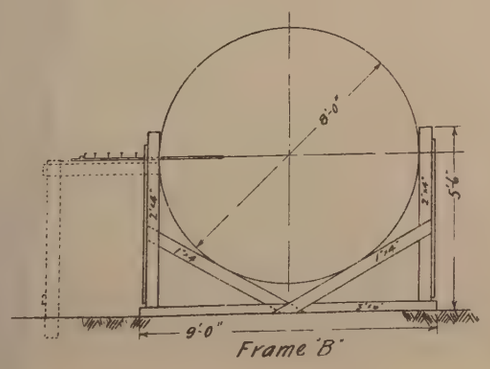


Velocity of Air	36" Disc Fan		A.C. Motor 300 to 600 R.P.M.	
Miles per Hr.	R.P.M.	Size of Pulley	R.P.M.	Size of Pulley
5	77	36"	346	8"
10	154	21"	404	8"
15	232	21"	609	8"
20	309	21"	433	15"
25	386	21"	541	15"

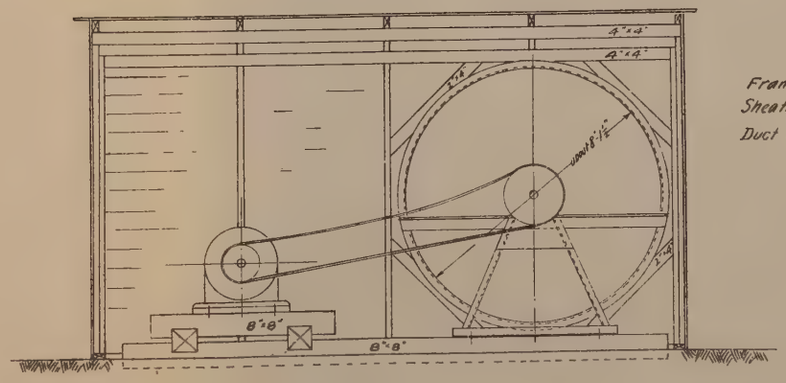




Frame "A"



Frame "B"



Frame of Shack 2"x4"
Sheathing on Sides & Roof 1".
Duct to be made of #15 Galvanized Iron.

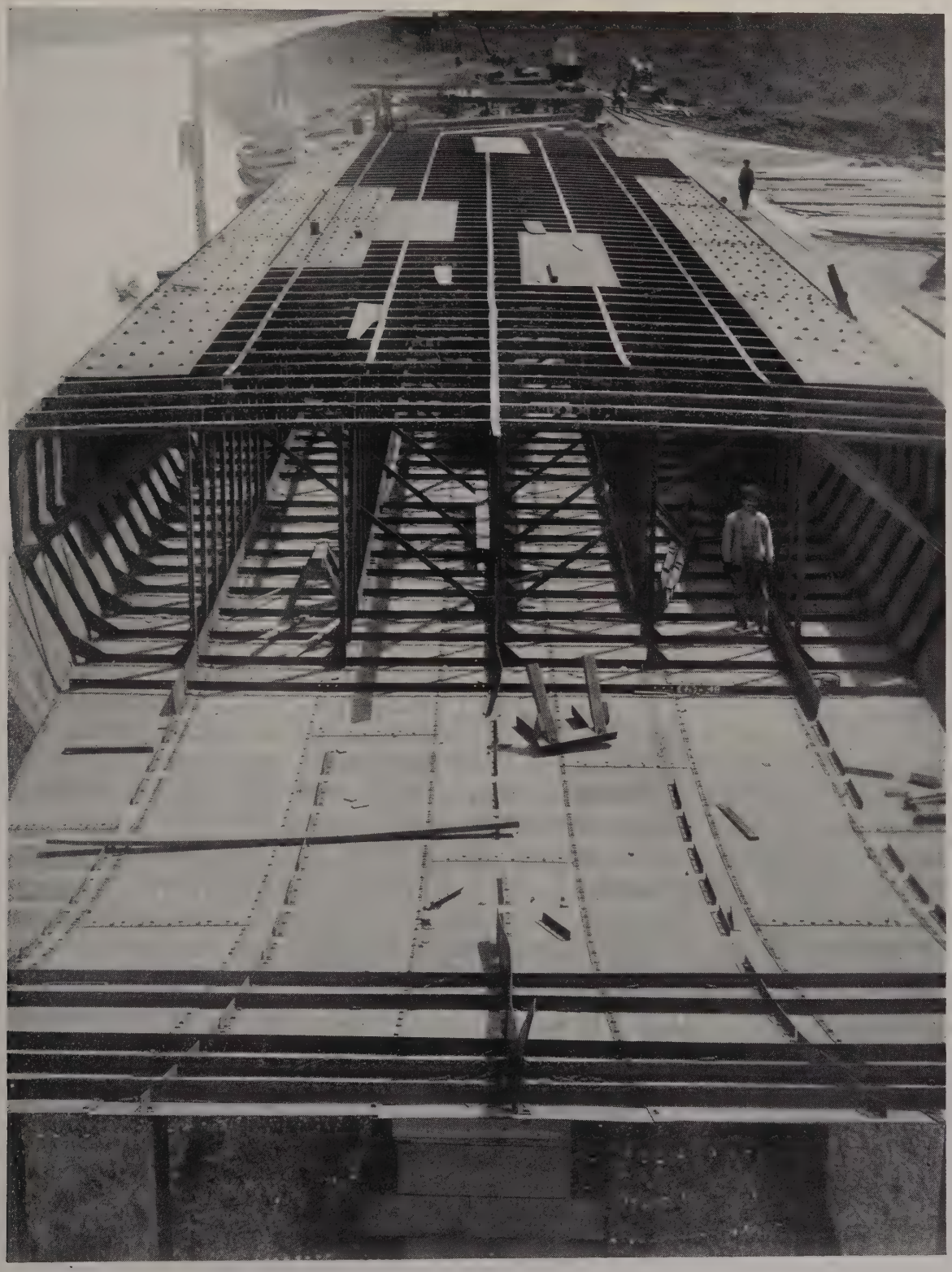
To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

TYPICAL STERN-WHEEL RIVER STEAMER.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

CONTRAST BETWEEN MODERN SELF-PROPELLED BARGE AND STERN-WHEEL RIVER STEAMERS.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*



ILLUSTRATING METHOD OF CONSTRUCTION OF MODERN BARGE HULLS.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Modern Barge Hull Ready for Launching.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Self-Propelled Barge, Fully Loaded, on Her Way from New Orleans to St. Paul, Showing Flat Wake.

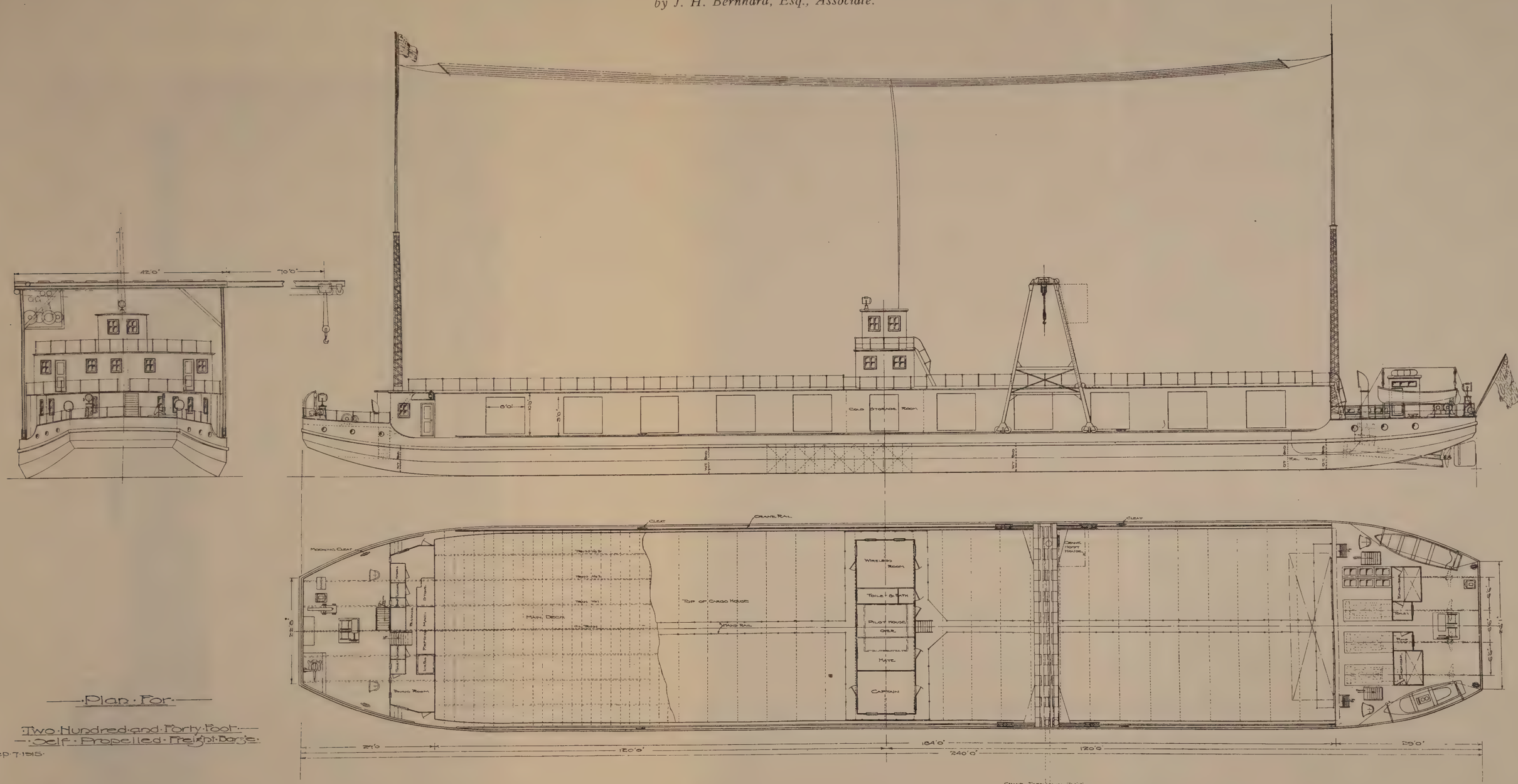
To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Showing Modern Barge Running Light.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Self-Propelled Fuel Lighter, with Elevator.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*


42'0"
70'0"
Cold Storage Room
Cargo Hatch
Cleat
Grand Rail
Mooring Cleat
Top of Cargo House
Main Deck
Hand Rail
Wireless Room
Toilet & Bath
Pilot House Over
Mate
Captain
Engine Room
Deck Room
Crew Toilet
Crew Mess
Crew Mess
Oil Tanks
Fresh Water
Steering Gear

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Barge No. 1, November 16, 1915, 10 A.M.

To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Launching Barge No. 1, November 16, 1915.

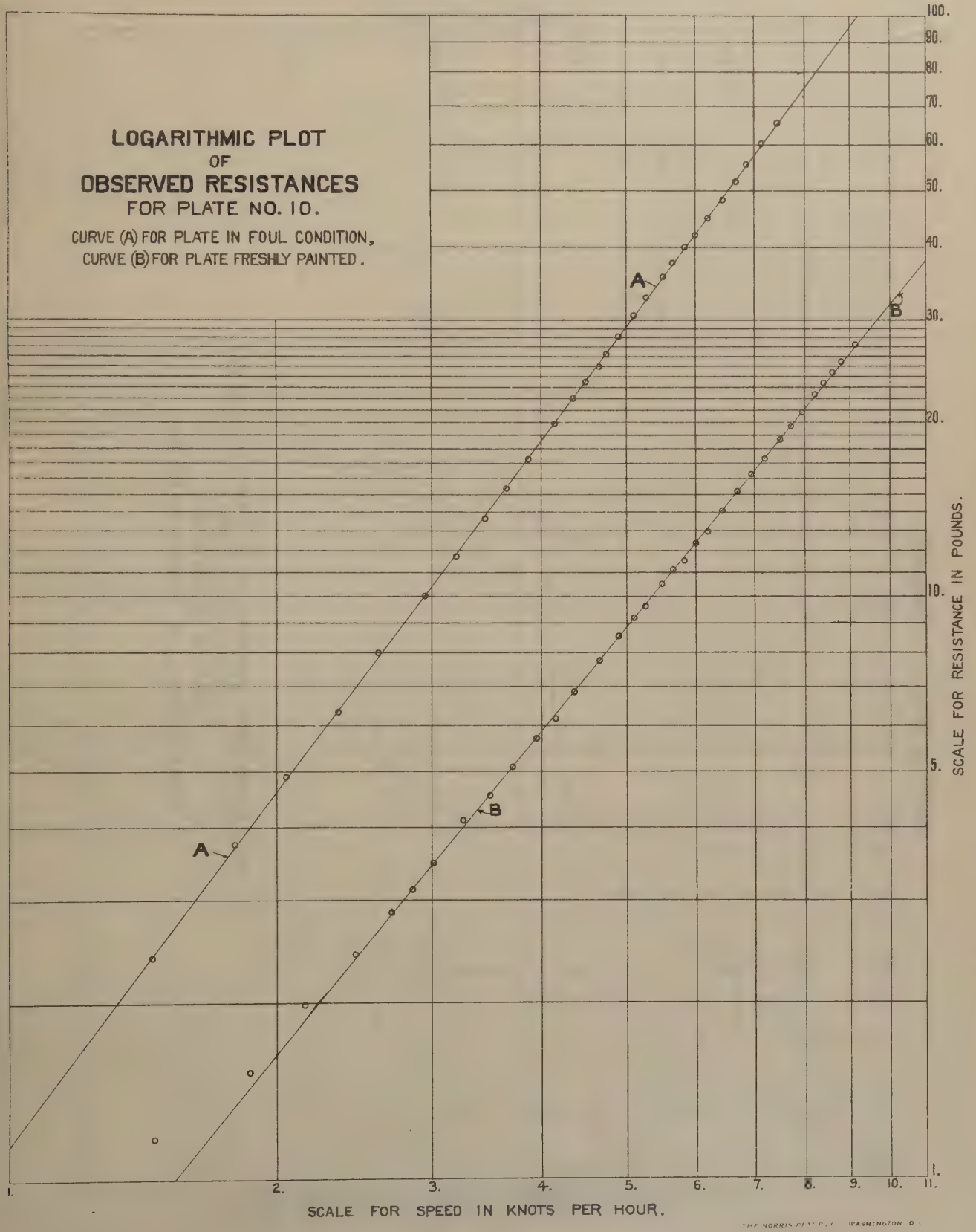
To illustrate paper on "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

Barge No. 1, November 16, 1915, Immediately After Launching.

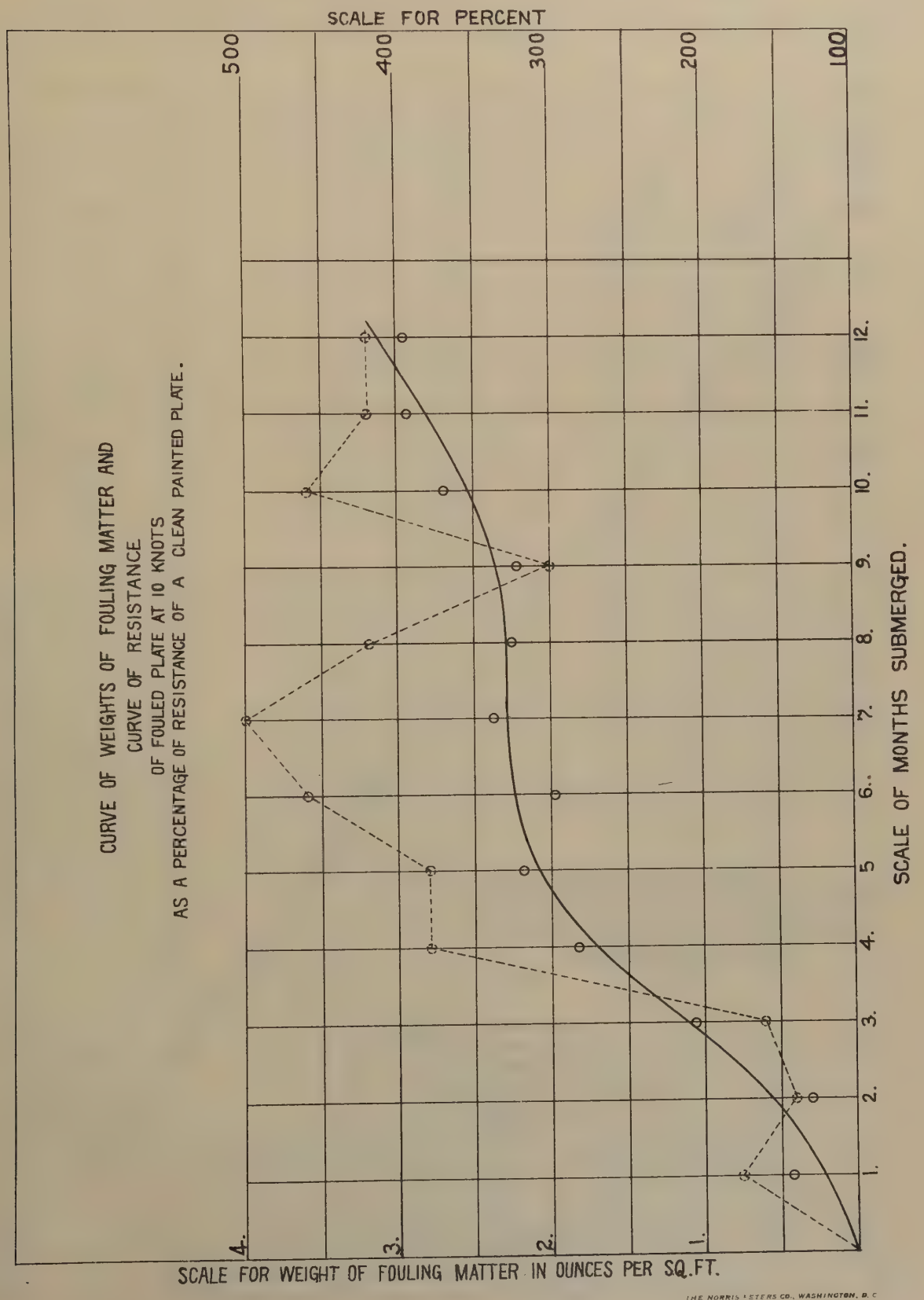
To illustrate discussion by Parker H. Kemble, Esq., on paper entitled "Inland Navigation and Barge Construction vs. *Floating Bridges," by J. H. Bernhard, Esq., Associate.*

GARIG. MISSISSIPPI RIVER, 1914.

To illustrate paper on "Variation of Frictional Resistance of Ships with Condition of Wetted Surface," by Naval Constructor William McEntee, U. S. N., Member.

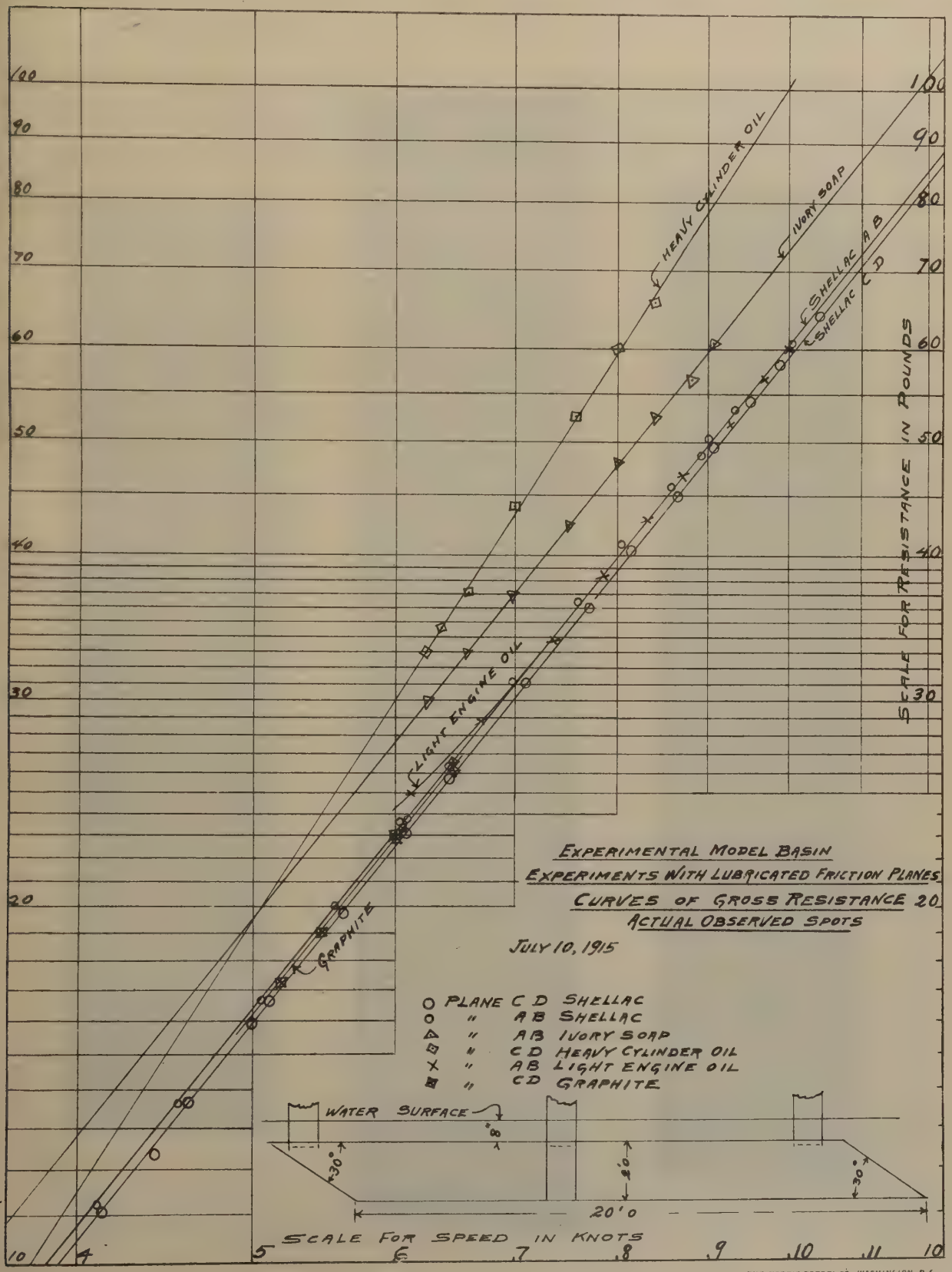


To illustrate paper on "Variation of Frictional Resistance of Ships with Condition of Wetted Surface," by Naval Constructor William McEntee, U. S. N., Member.



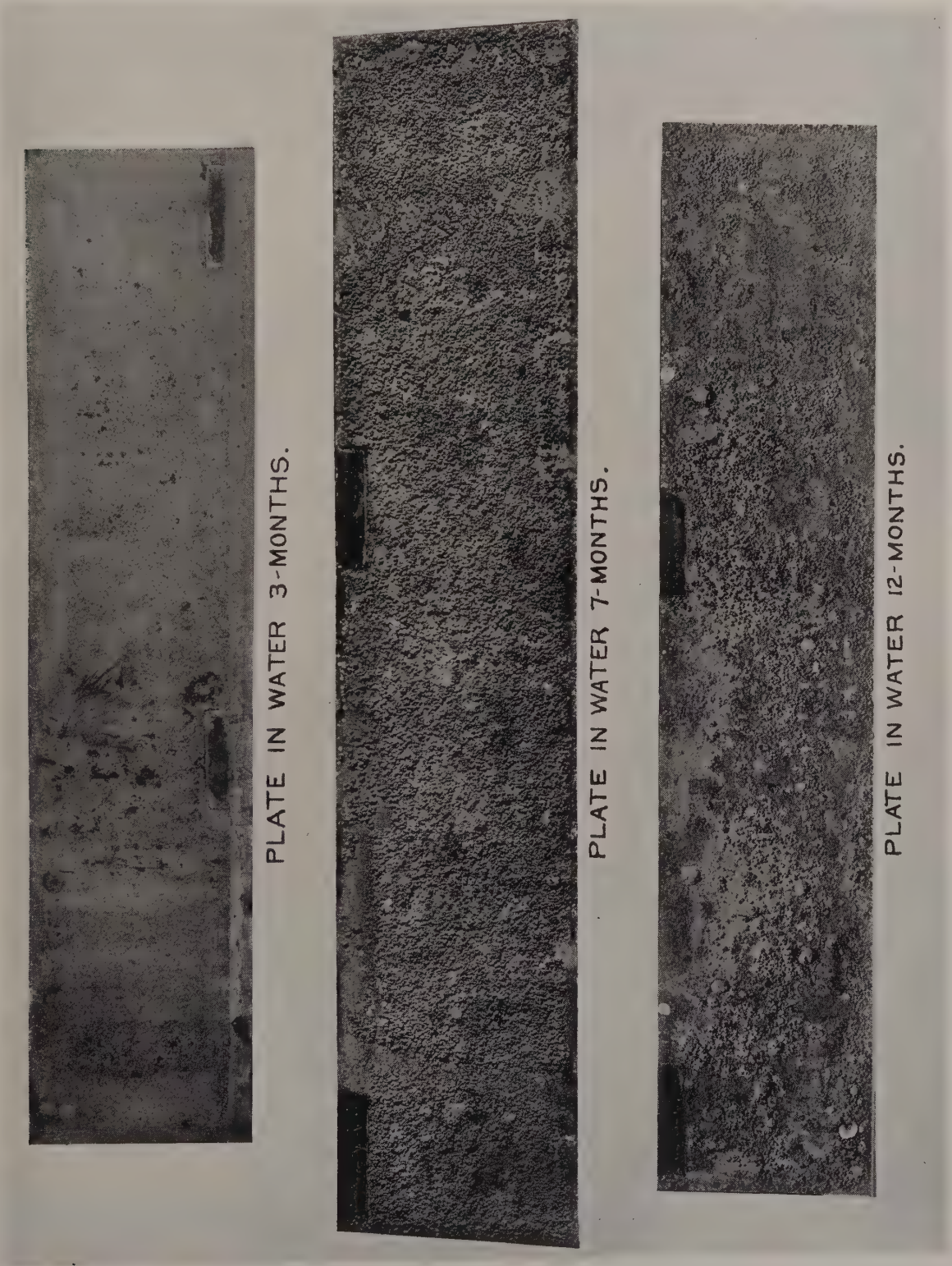
THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Variation of Frictional Resistance of Ships with Condition of Wetted Surface," by Naval Constructor William McEntee, U. S. N., Member.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Variation of Frictional Resistance of Ships with Condition of Wetted Surface," by Naval Constructor William McEntee, U. S. N., Member.



To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

FIG. 1.—THE WIDGEON.

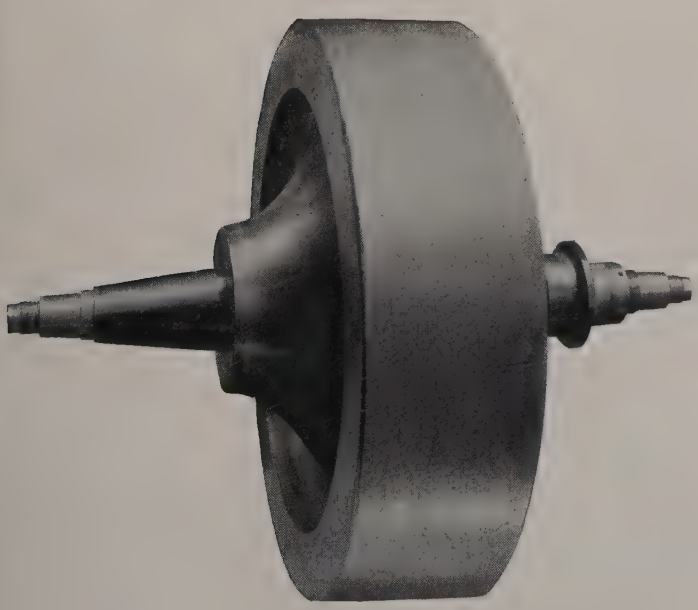


FIG. 2.

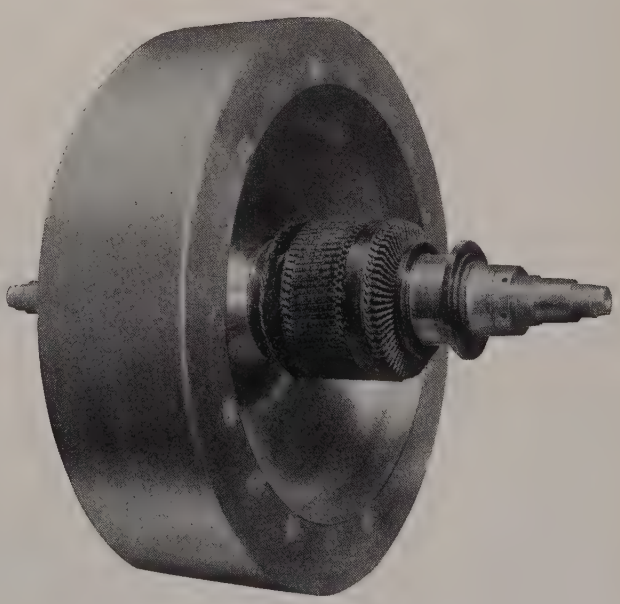


FIG. 3.

To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

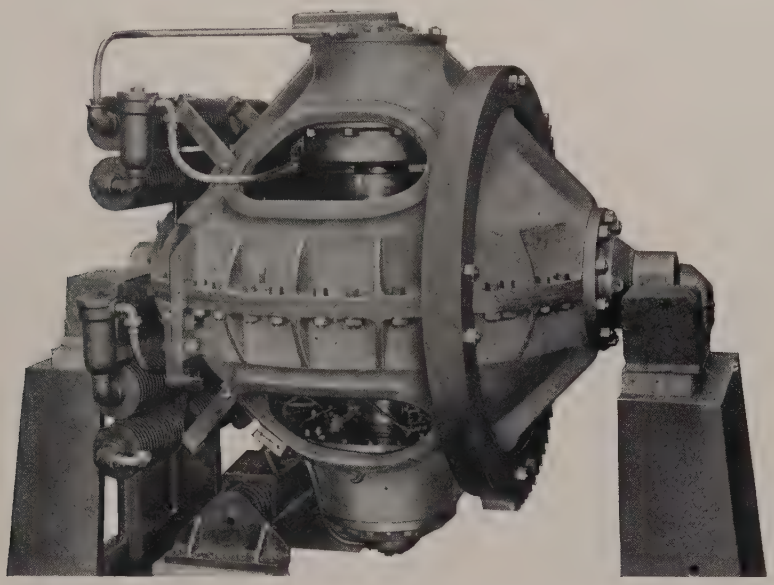


FIG. 4.

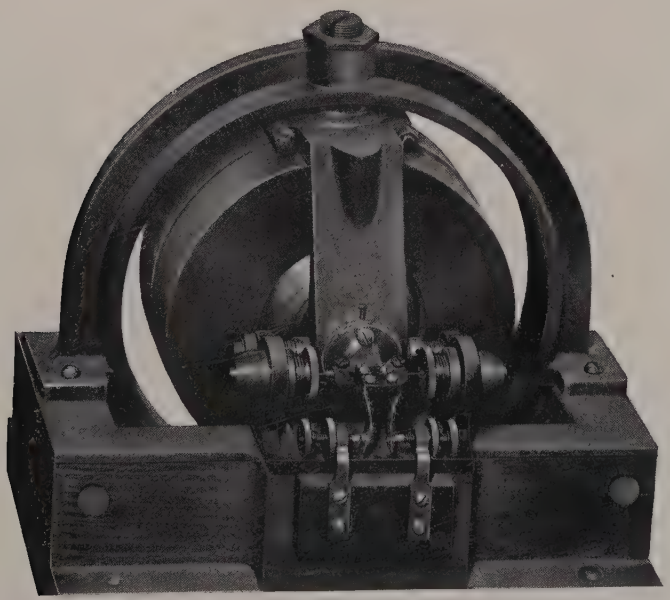


FIG. 5.

To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

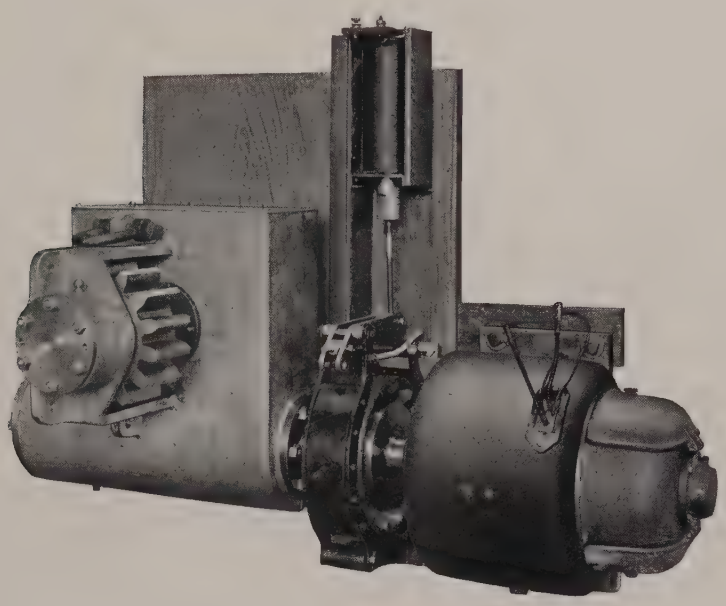


FIG. 6.

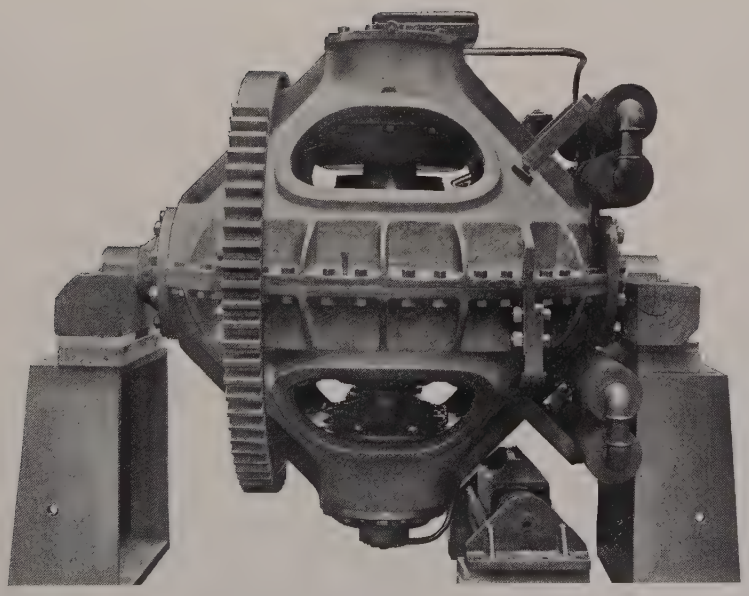


FIG. 7.

To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

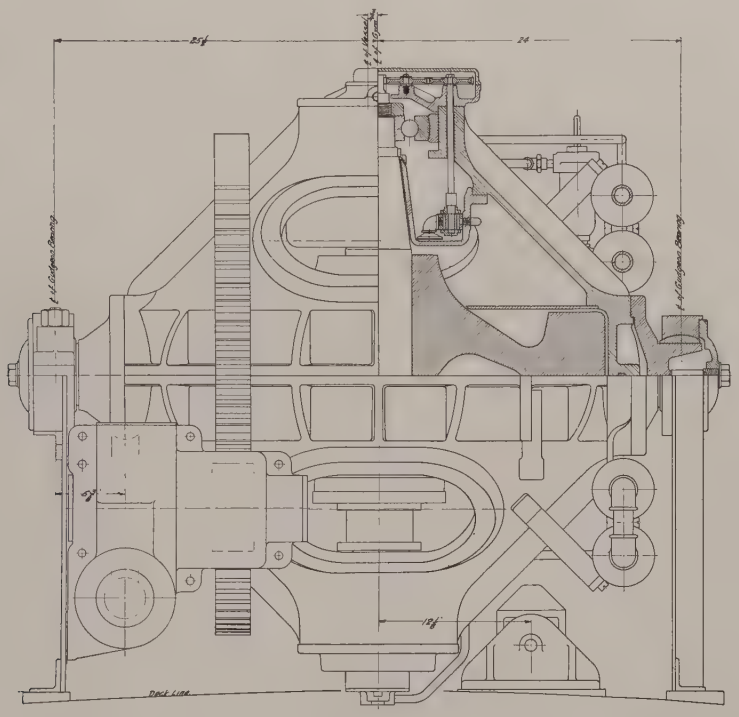


FIG. 8.

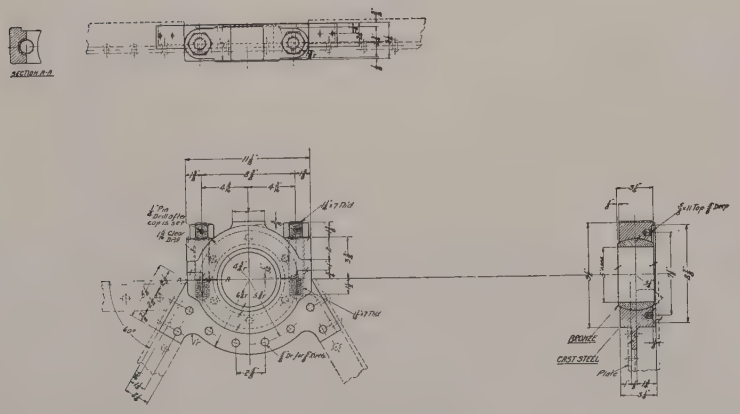


FIG. 9.

To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

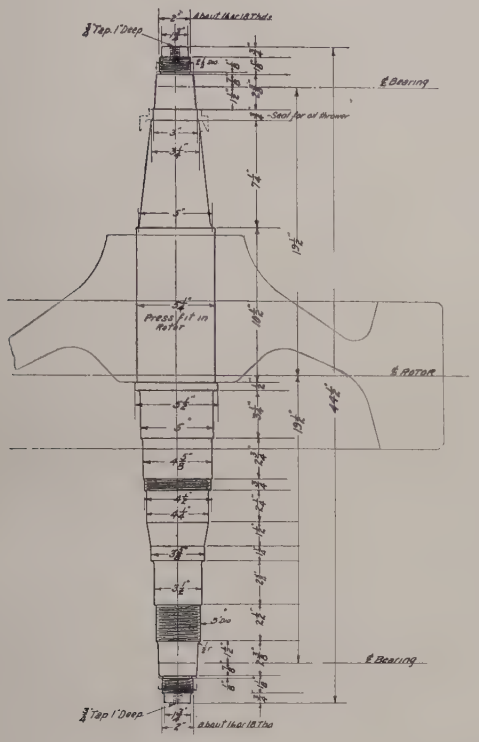


FIG. 11.

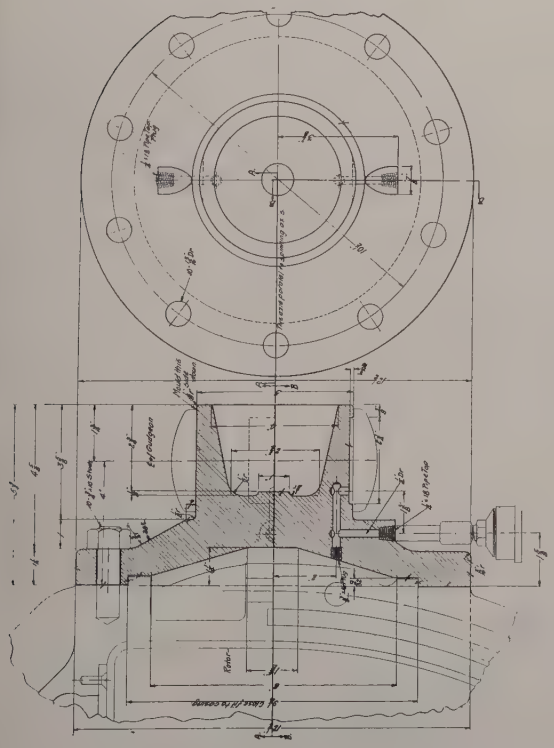


FIG. 10.

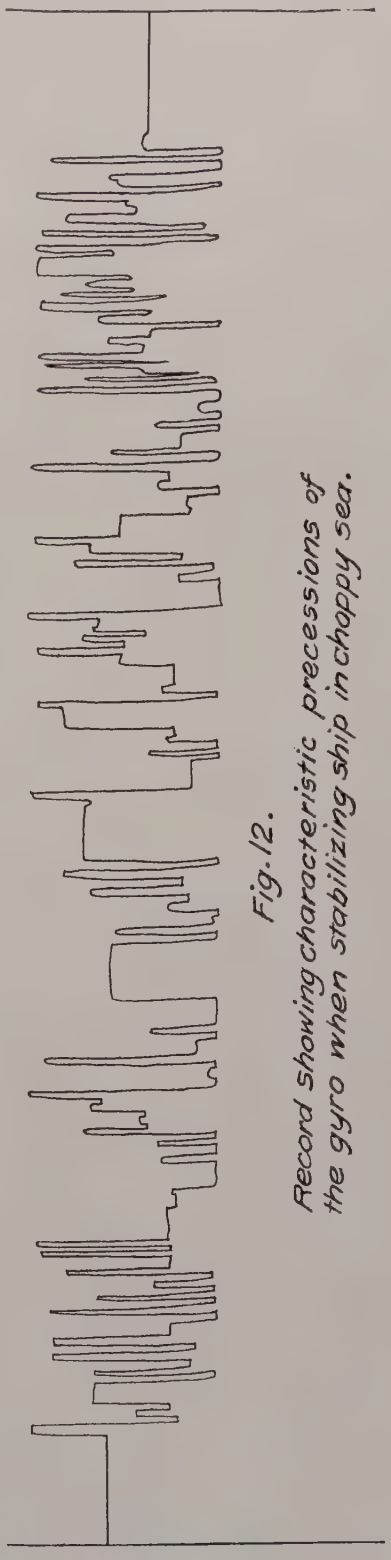


Fig. 12.
Record showing characteristic precessions of the gyro when stabilizing ship in choppy sea.

To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

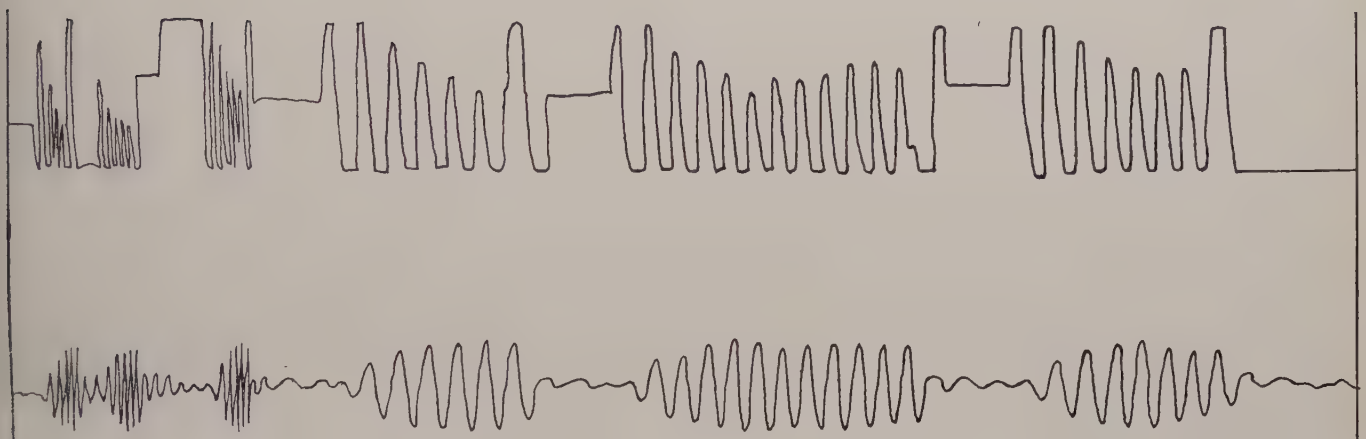


Fig. 13.
Records showing Rolling the ship by the gyro, about 8° total arc.
Gyro 1100 R.P.M.

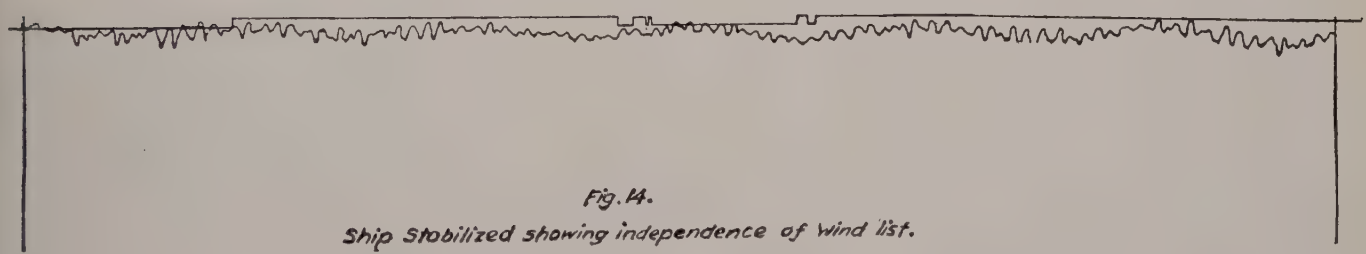


Fig. 14.
Ship Stabilized showing independence of wind list.

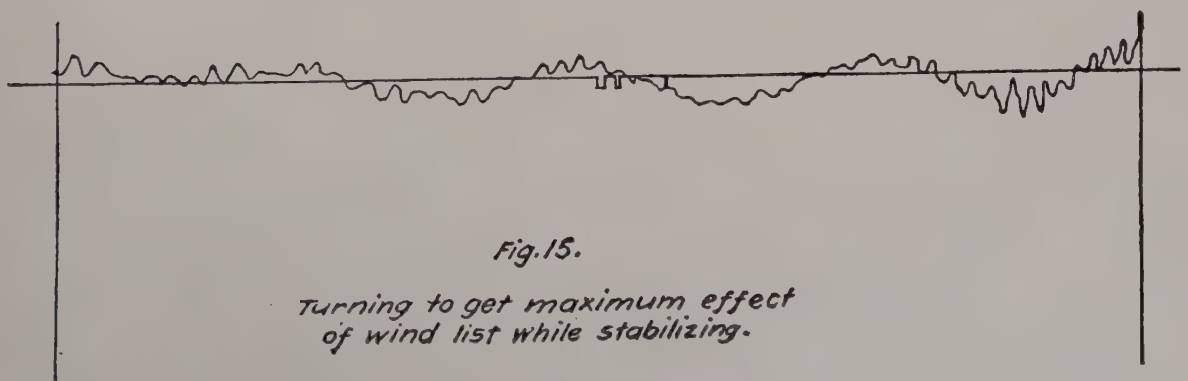


Fig. 15.
Turning to get maximum effect of wind list while stabilizing.

To illustrate paper on "Recent Progress with the Active Type of Gyro-Stabilizer for Ships," by Elmer A. Sperry, Esq., Member.

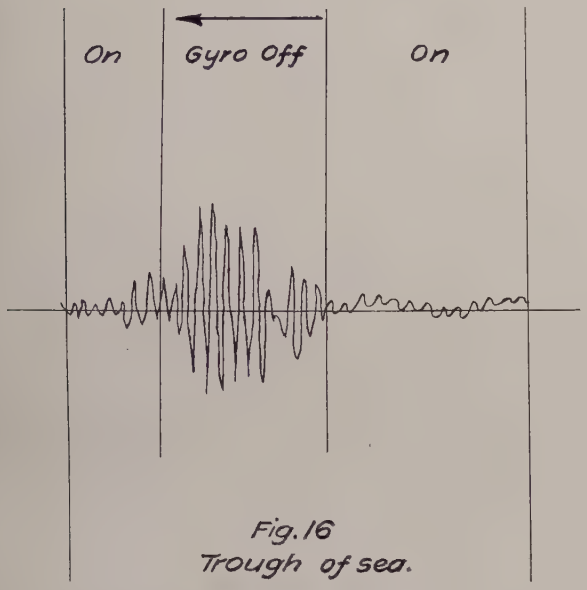


Fig. 16
Trough of sea.

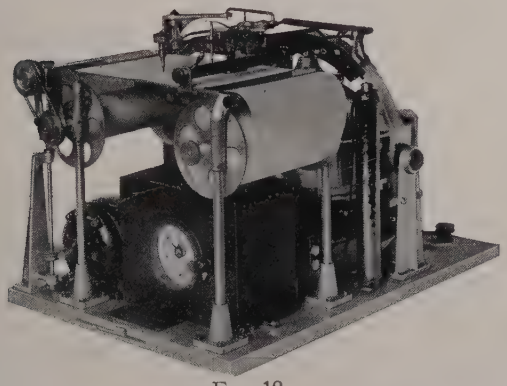


Fig. 18.

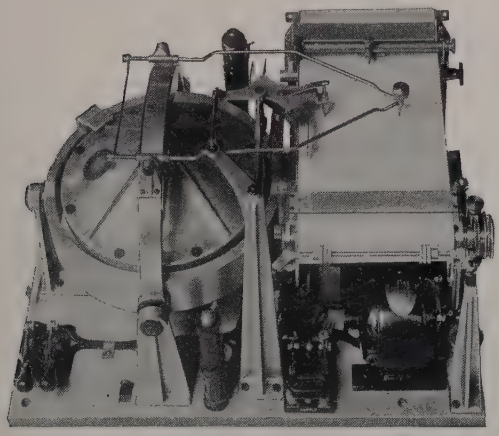


Fig. 18.

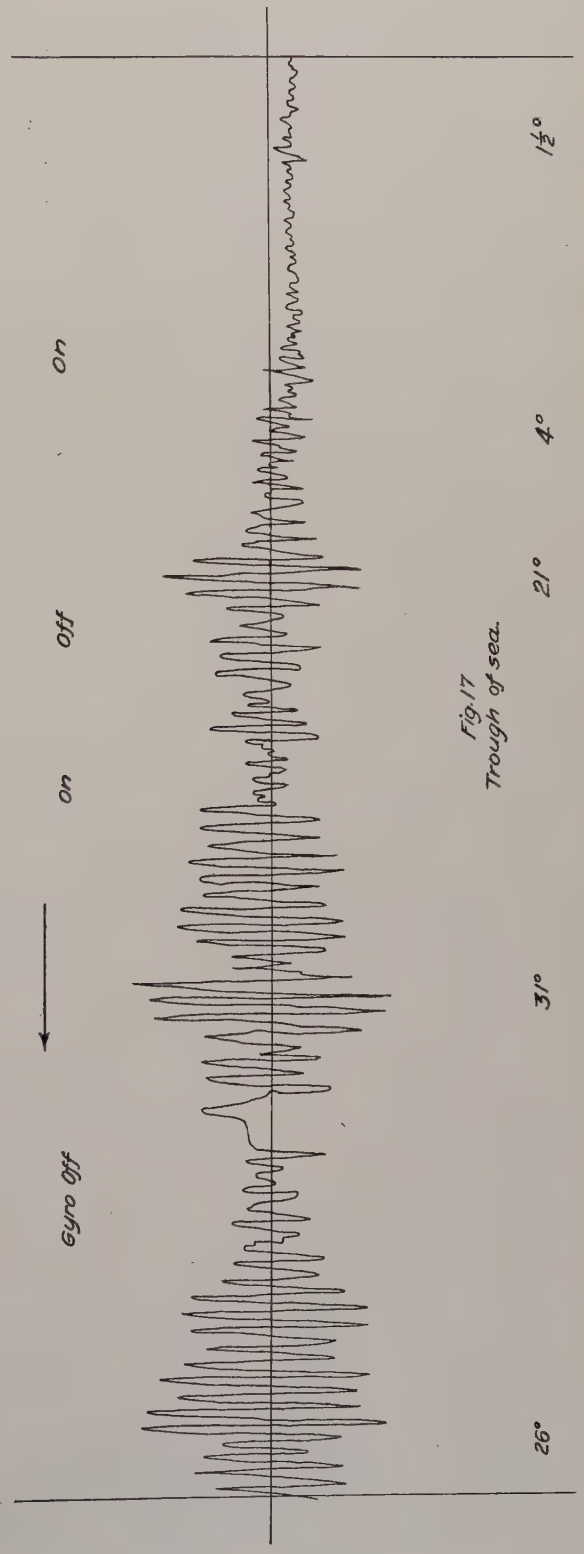
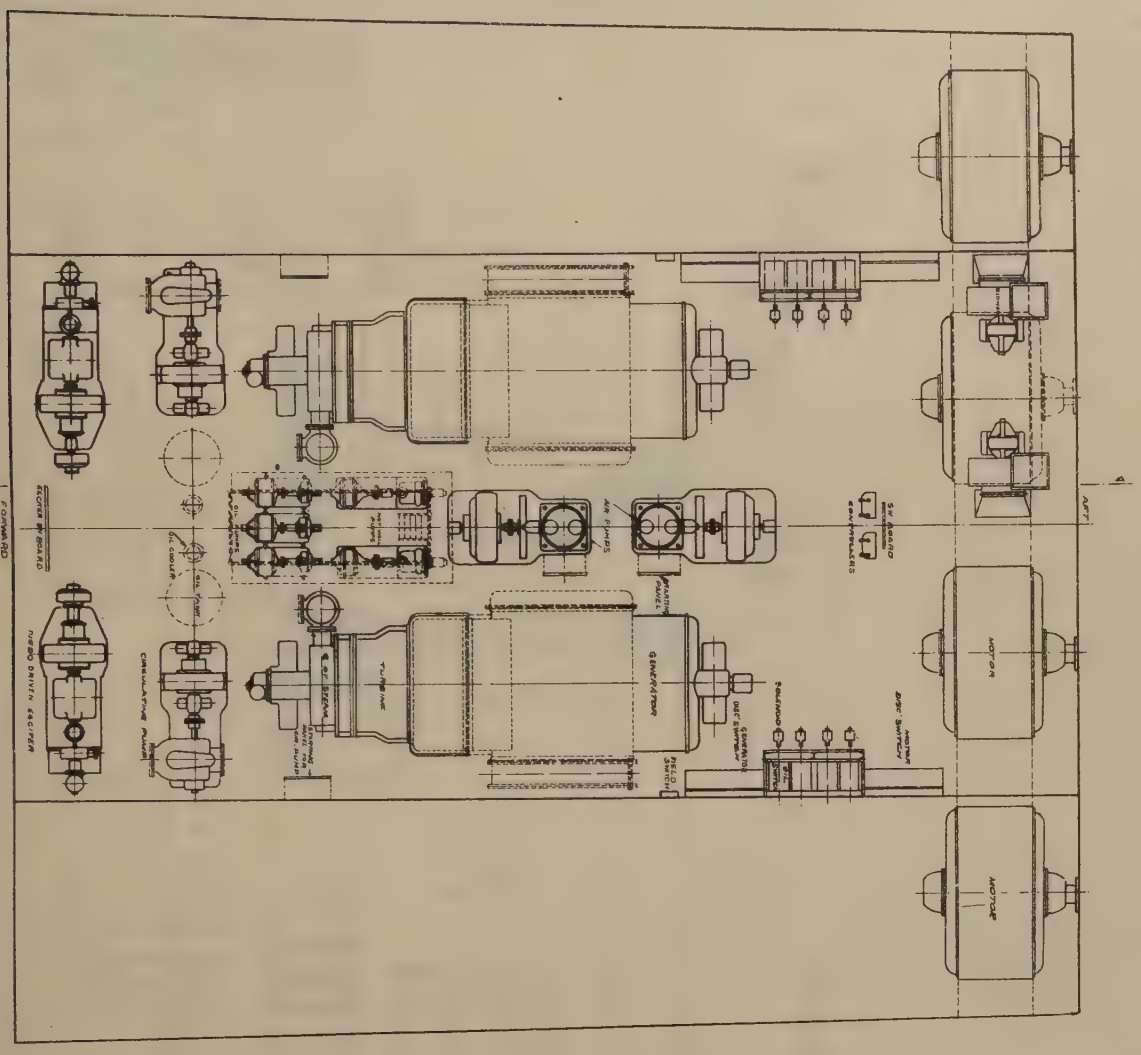
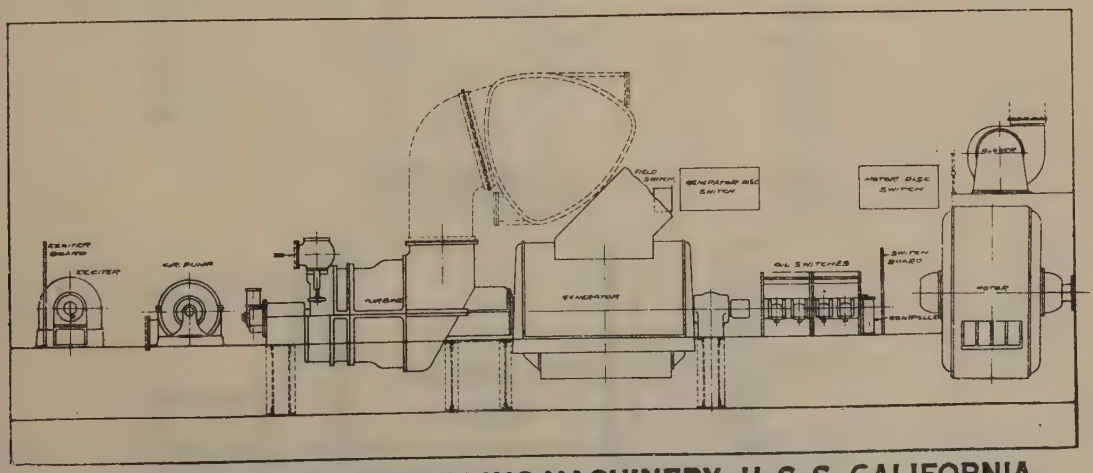


Fig. 17
Trough of sea.

To illustrate discussion by John F. Wentworth, Esq., on paper entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by W. L. R. Emmet, Esq., Member of Council.



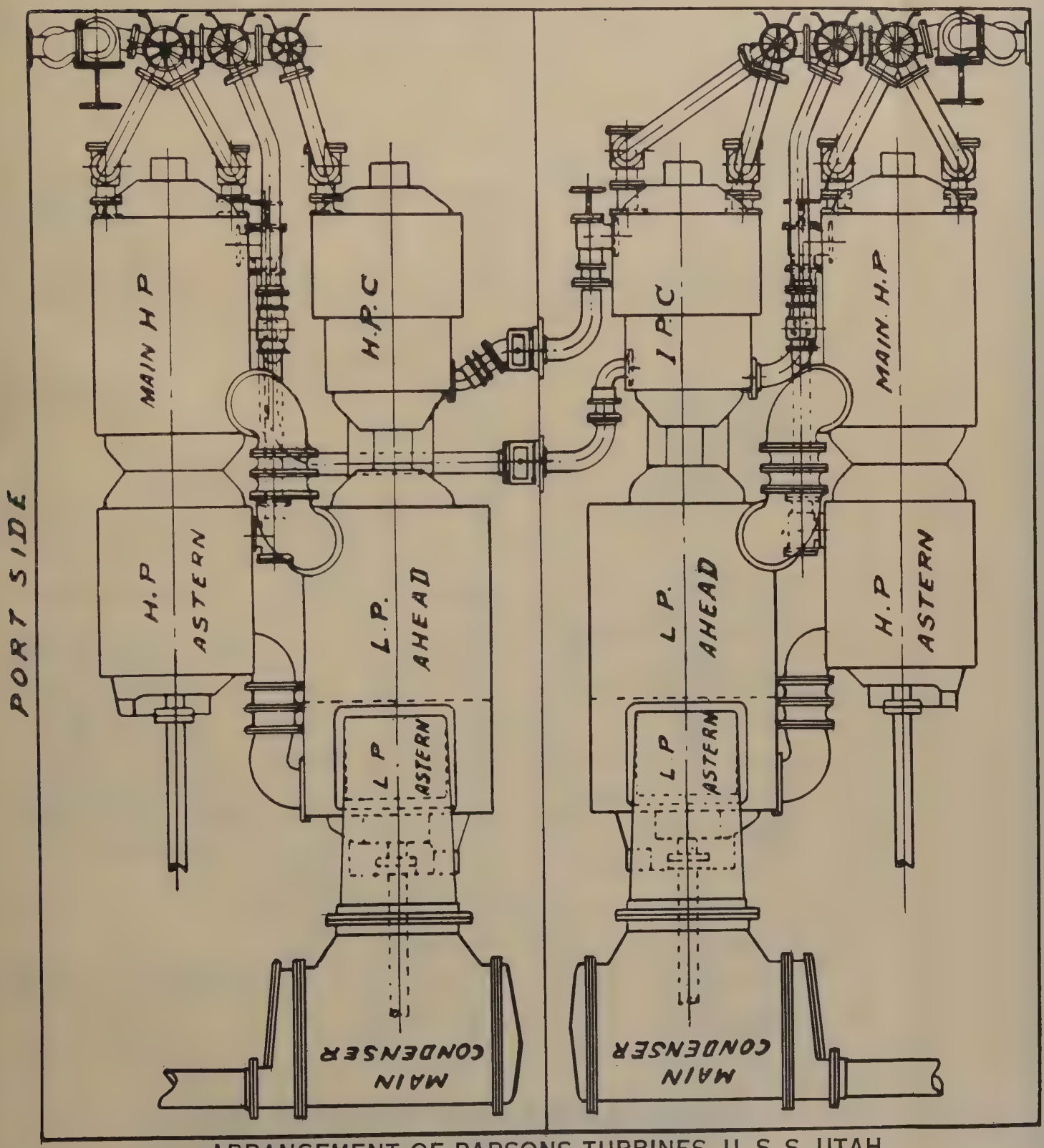


ARRANGEMENT OF PROPELLING MACHINERY, U. S. S. CALIFORNIA.

SUBJECT TO CHANGE. NOT FOR CONSTRUCTION UNLESS SPECIALLY APPROVED

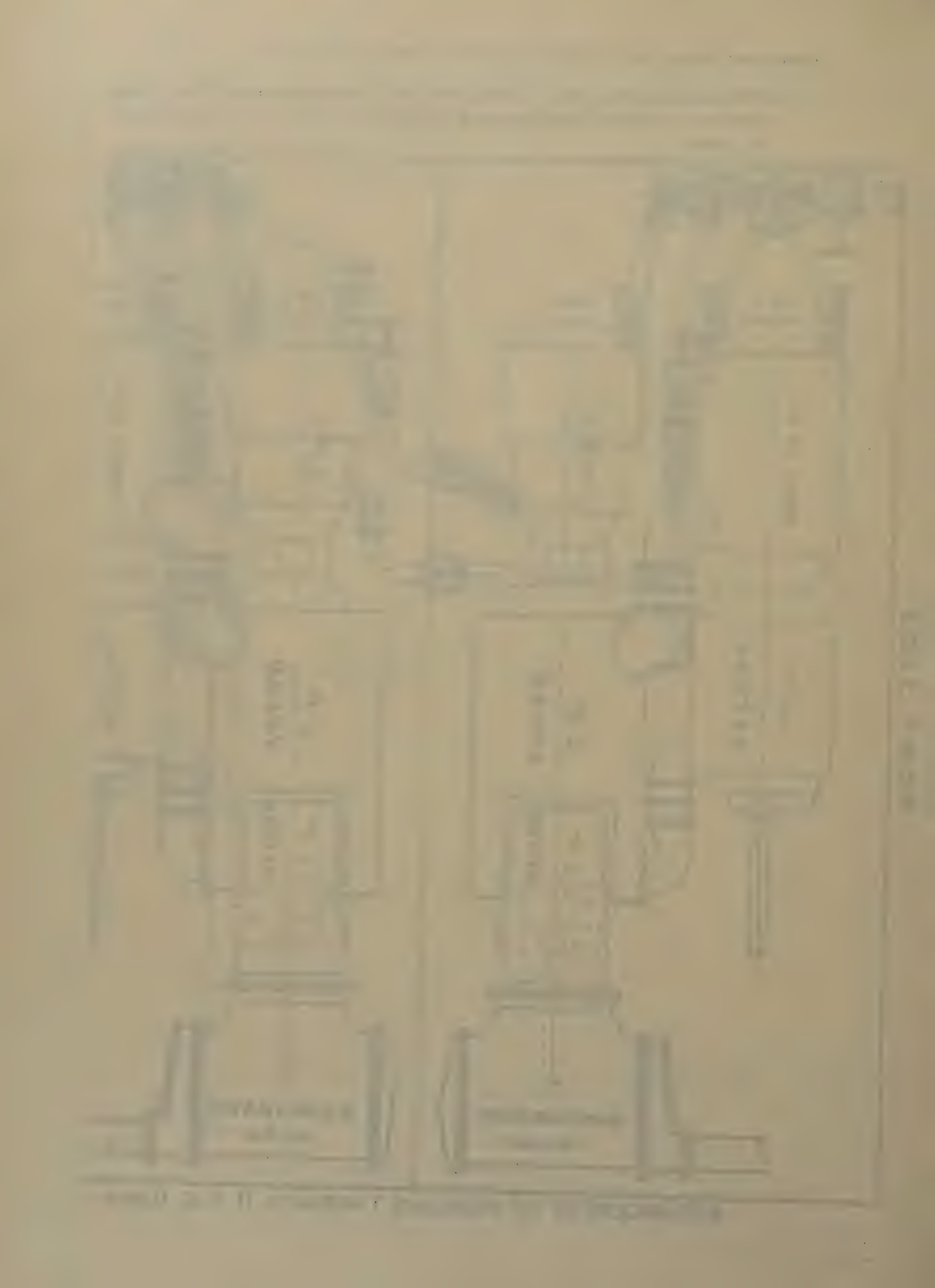
THE HORRIS PETERS CO., WASHINGTON, D. C.

To illustrate discussion by John F. Wentworth, Esq., on paper entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by W. L. R. Emmet, Esq., Member of Council.

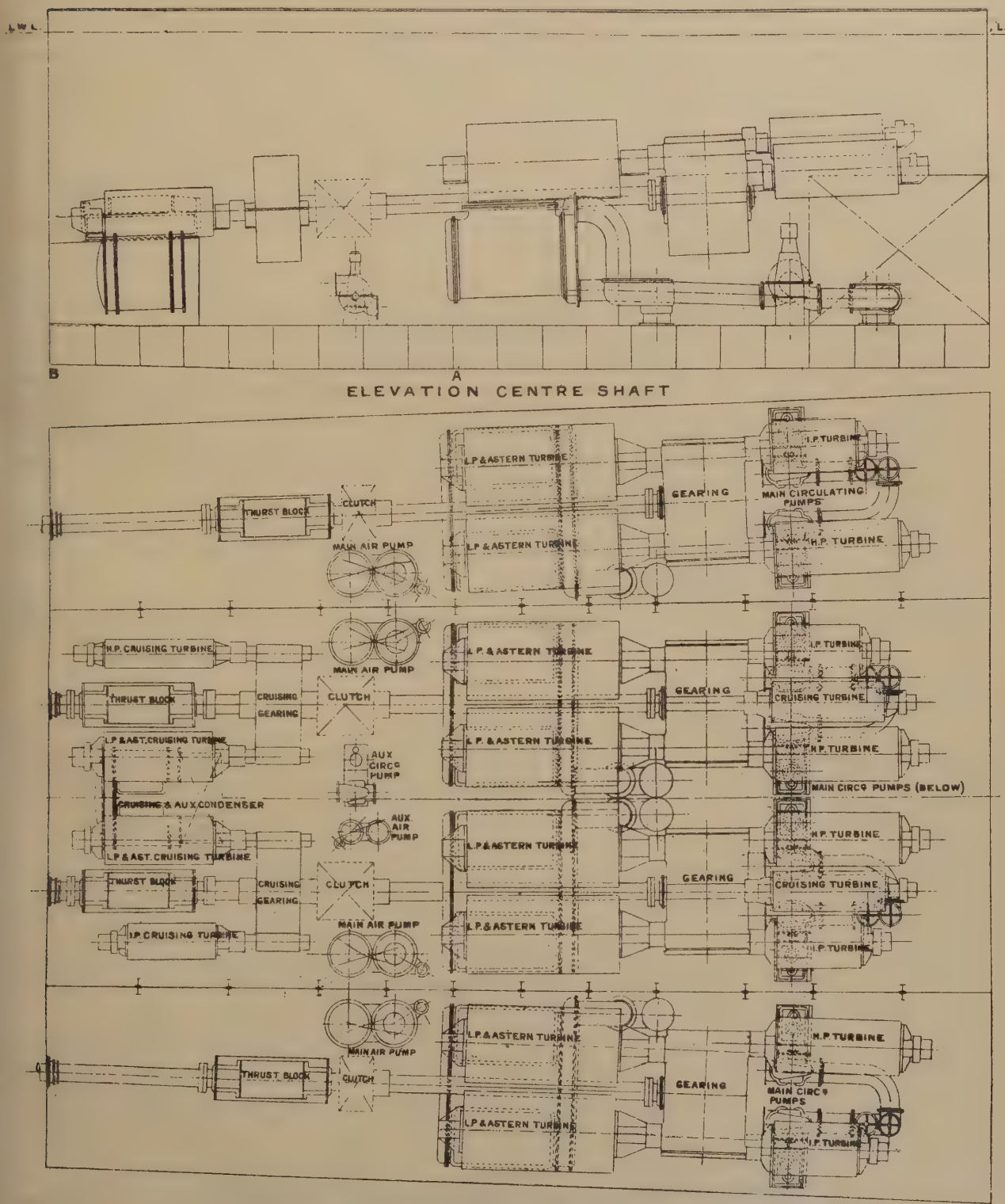


ARRANGEMENT OF PARSONS TURBINES, U. S. S. UTAH.

THE NORRIS PETER CO., WASHINGTON, D. C.



To illustrate discussion by John F. Wentworth, Esq.. on paper entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by W. L. R. Emmet, Esq., Member of Council.



PROPOSED ARRANGEMENT FOR A LARGE BATTLESHIP WITH PARSONS DRIVE, TAKEN FROM SIR CHARLES PARSONS' PAPER OF MARCH 13, 1913.

THE NORRIS PETERS CO., WASHINGTON, D. C

To illustrate discussion by John F. Wentworth, Esq., on paper entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by W. L. R. Emmet, Esq., Member of Council.

FACTOR 1 TON OF COAL PER DAY AT 14600 B.T.U. = 536 H.P. (100% EFF.)

PROOF $\frac{2240(\text{LBS}) \times 14600\ \text{BTU} \times 778\ \text{FT.LBS.}}{33000 \times 60 \times 24} = 536\ \text{H.P.}$

EFFICIENCY = $\frac{\text{HORSE POWER}}{\text{TONS COAL PER DAY} \times 536}$

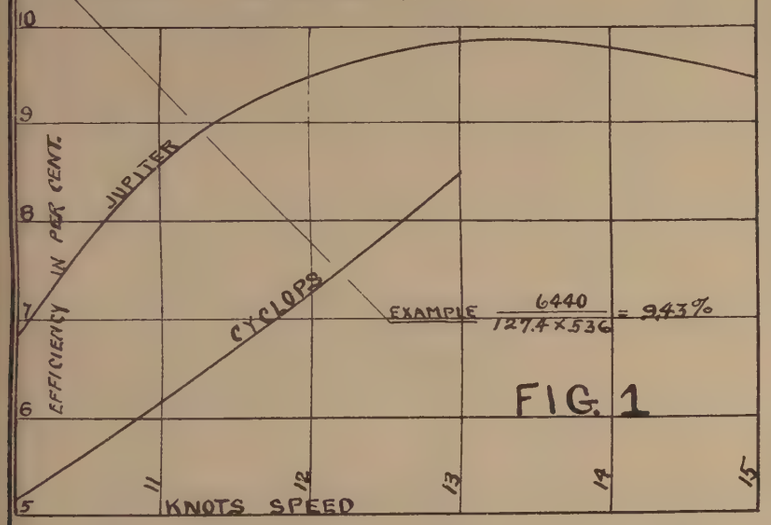


FIG. 1

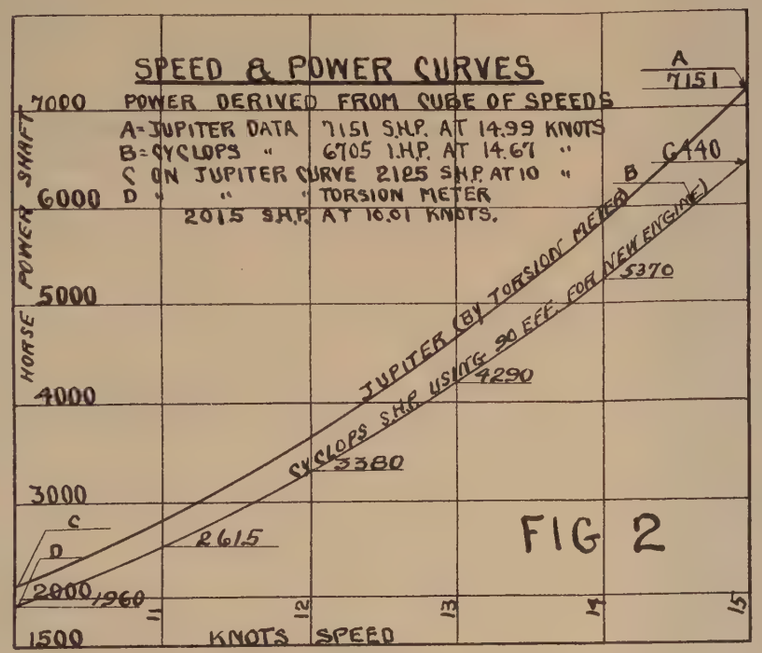

SPEED & POWER CURVES
POWER DERIVED FROM CUBE OF SPEEDS
A=JUPITER DATA 7151 S.H.P. AT 14.99 KNOTS
B=CYCLOPS " 6705 I.H.P. AT 14.67 "
C ON JUPITER CURVE 2125 S.H.P. AT 10 "
D " " " TORSION METER
2015 S.H.P. AT 10.01 KNOTS.
HORSE POWER SHAFT
JUPITER (BY TORSION METER)
CYCLOPS S.H.P. USING 90 EFF. FOR NEW ENGINES
KNOTS SPEED

FIG 2

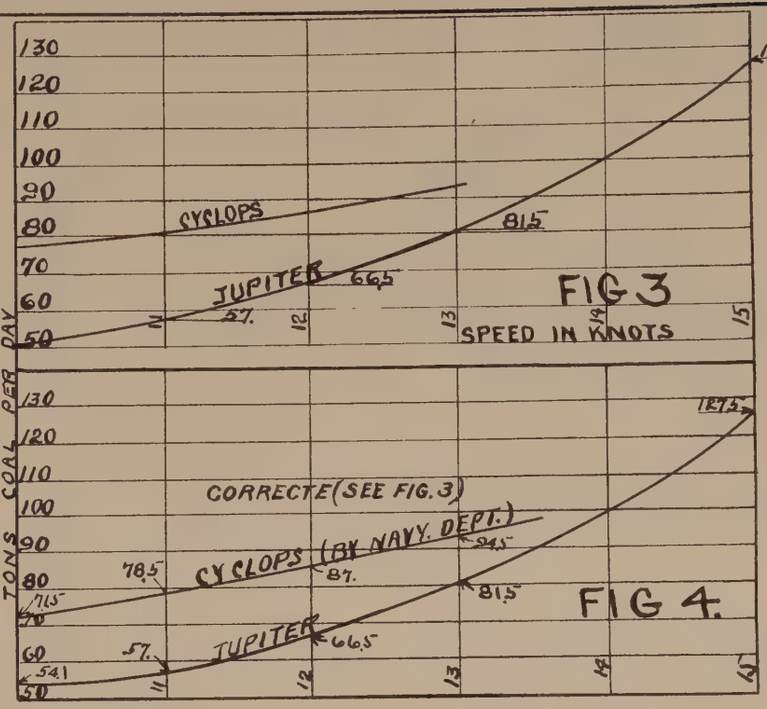


FIG 3

FIG 4.

STEAM CONSUMPTIONS

JUPITER

	GUARANTEED	REPORTED	CORRECTED
10 KNOTS	15 LBS.	12.316	12.65
15 "	13 "	11.68	12.95

CALIFORNIA GUARANTEED

10 KNOTS	14.6 LBS.
15 "	11.4 "
19 "	11.1 "
MAXIMUM	11.9 "

JUPITER DATA

SPEED KNOTS	14.99	10.01
DATE	FEB. 14 '14	FEB. 18 '14
DURATION HOURS	48	24
DISP. TONS	19,452	19,350
PRESS. AT TURB.	168.4	180.56
SHAFT HORSE POWER	7151	2015.
STEAM PER HOUR TURB.	83,552.	24,820
" " " AUX.	22,212	15,246
TONS COAL PER DAY	127.4	54.1

To illustrate discussion by E. H. B. Anderson, Esq., on paper entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by W. L. R. Emmet, Esq., Member of Council.

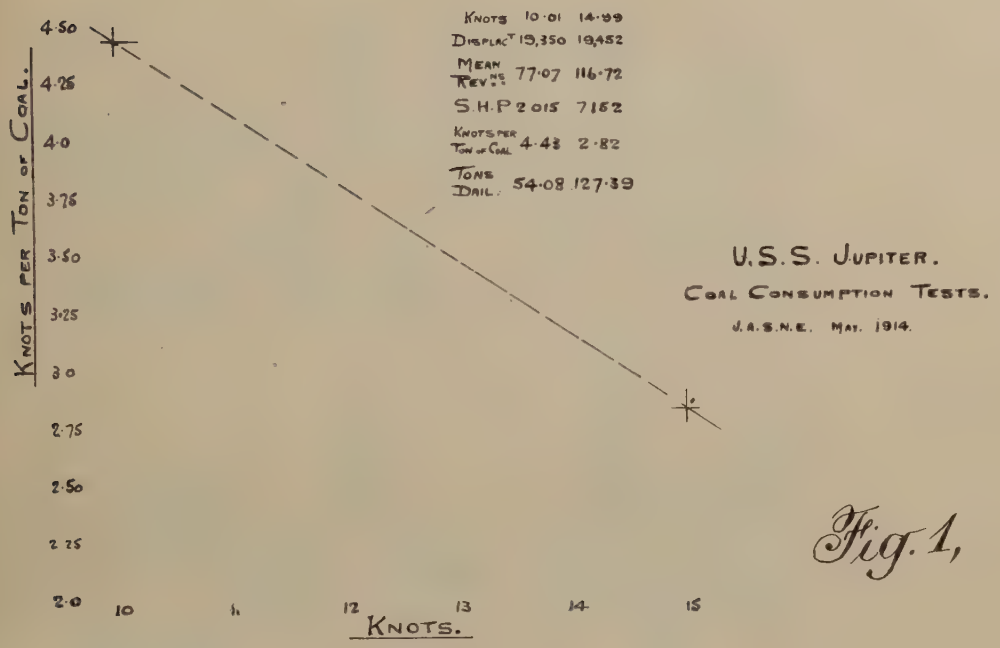


Fig. 1,

Number	1	2	3	4	5	6	
Name	Ulysses	Achilles	Cyclops	Proteus	Nereus	Orion	Jupiter
Knots	14·60	14·28	14·61	14·67	14·57	14·47	14·99
Displ^t	19.336	19,372	19,095	19.060	18,838	18,800	19.452
N^o Hours on Trial	24	24	48	18	18	48	48
	Twin Reciprocating Engines						Electric Motors
Mean Rev^ns	96·46	92·80	92·22	101·50	99·07	95	116·72
Knots per Ton of Coal	2·829	3·304	3·288	3·001	3·08	3·093	2·82

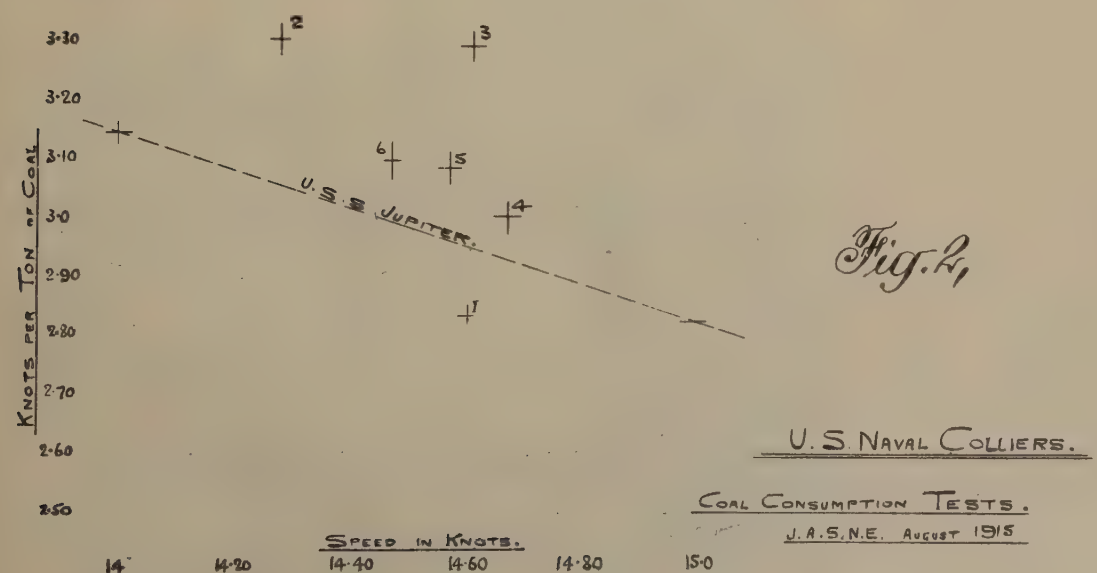


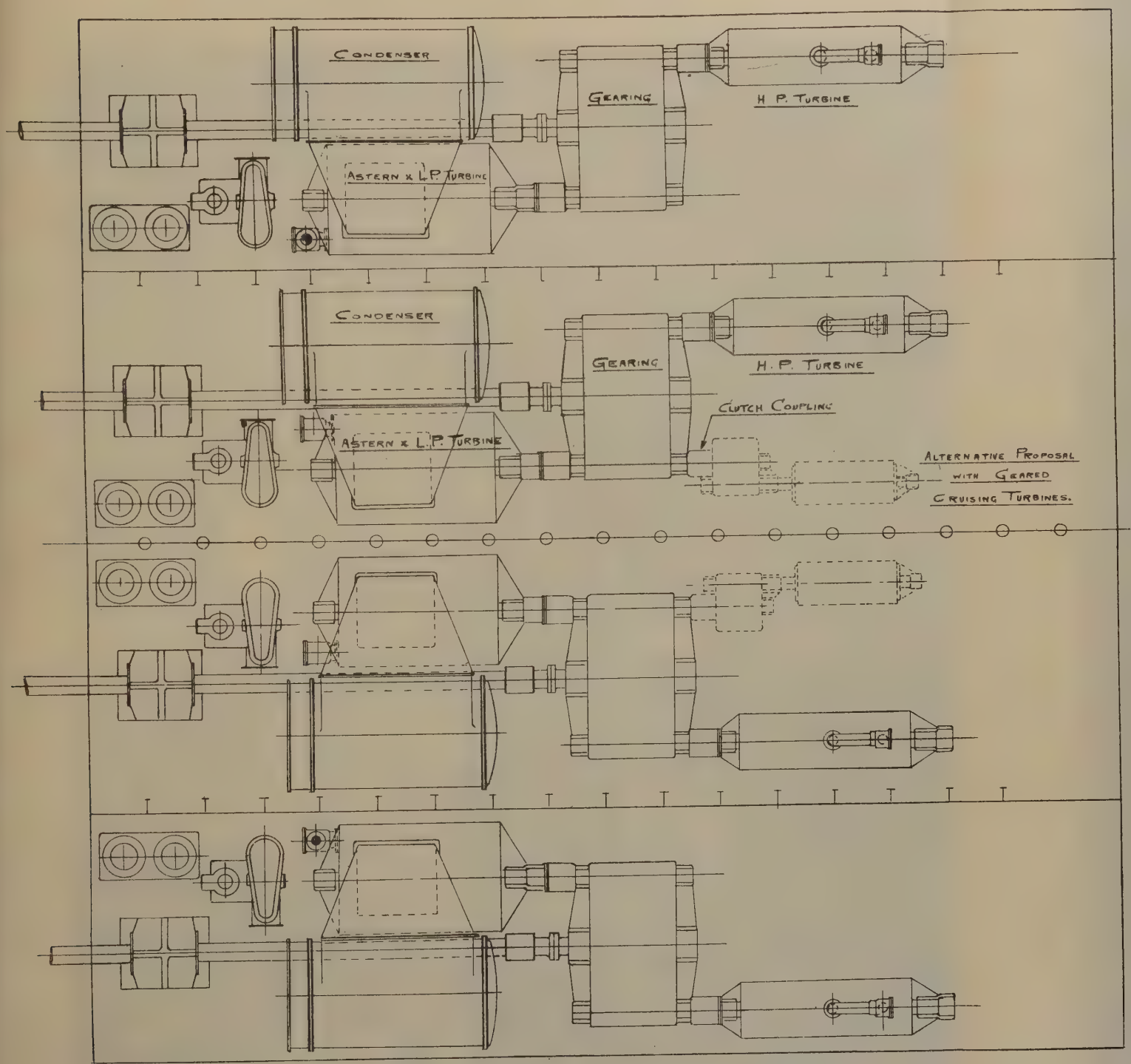
Fig. 2,

U.S. Naval Colliers.

Coal Consumption Tests.

J.A.S.N.E. August 1915

To illustrate discussion by E. H. B. Anderson, Esq., on paper entitled "Some Comparisons Relating to Electric Propulsion of a Battleship," by W. L. R. Emmet, Esq., Member of Council.



U. S. BATTLESHIPS.

PROPOSED ARRANGEMENT OF GEARED TURBINE MACHINERY.

Fig. 3

To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

S. S. Great Northern. Dining Saloon.

To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

S. S. Great Northern. First Class Lounge.

To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

S. S. Great Northern. First Class Smoking Room.

To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

STEAMER COMMONWEALTH. VENETIAN GOTHIC SALOON.

To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

S. S. Great Northern. Stairs at Writing Room Level.

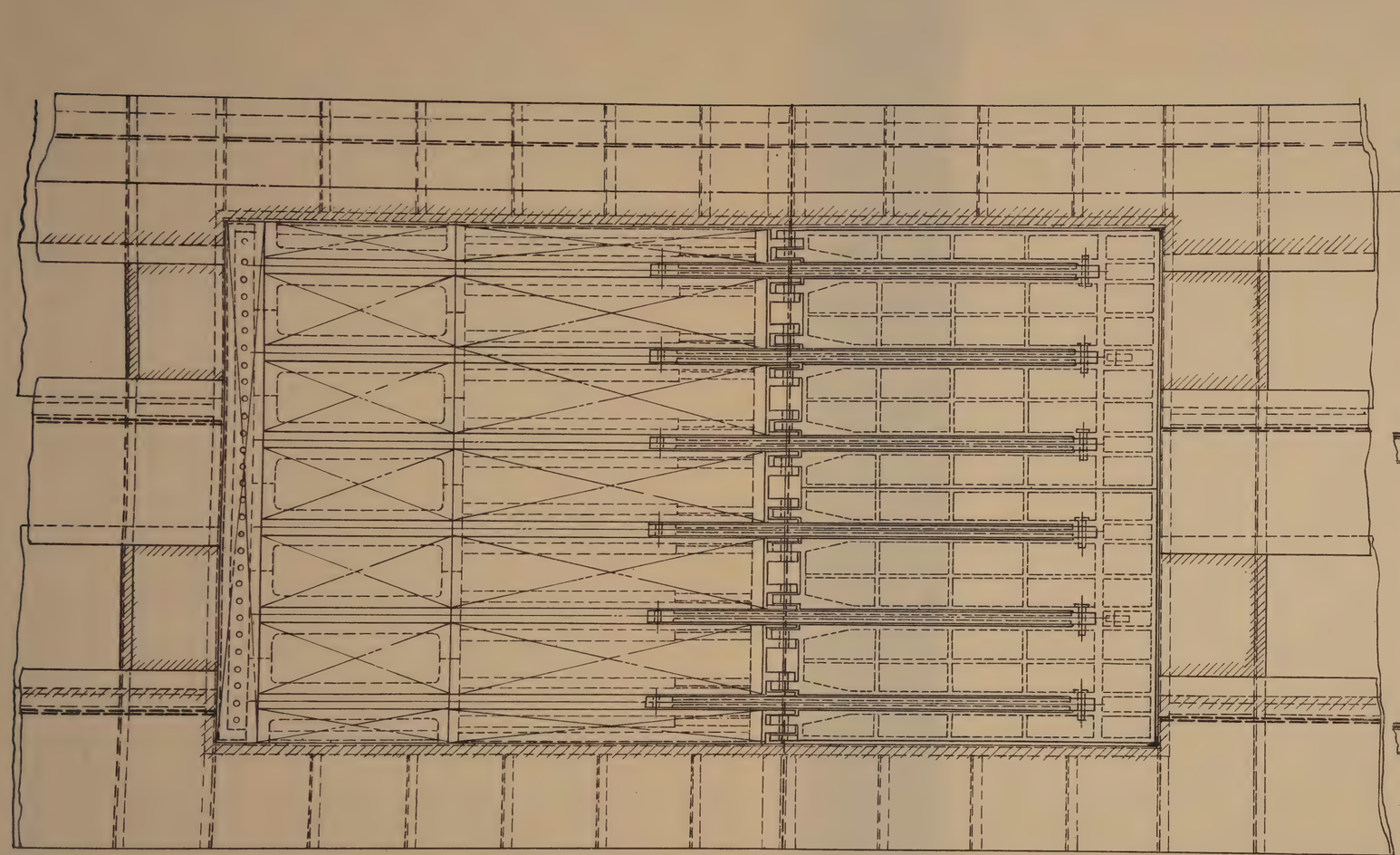
To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

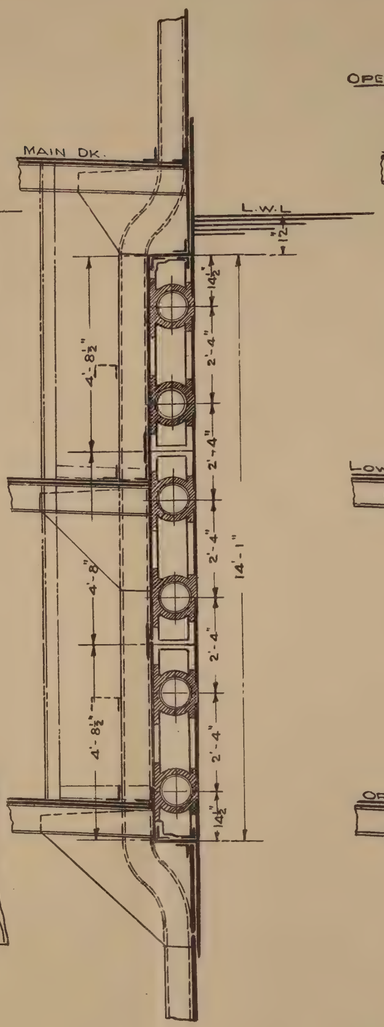
S. S. Great Northern. Head of Stairs at Promenade Deck Entrance.

To illustrate paper on "Interior Decoration of Vessels," by Harry B. Etter, Esq., Associate.

S. S. Great Northern. Observation Room.

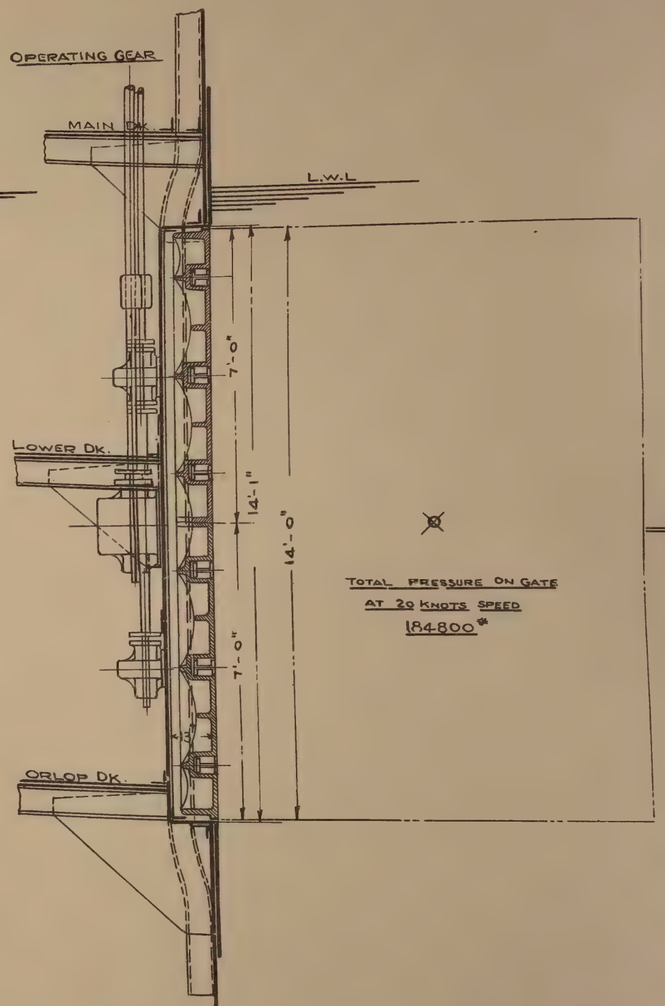
To illustrate paper on "Results of Model Tank Experiments to Determine the Action of a Ship Brake," by Captain William Strother Smith, U. S. N., Member.





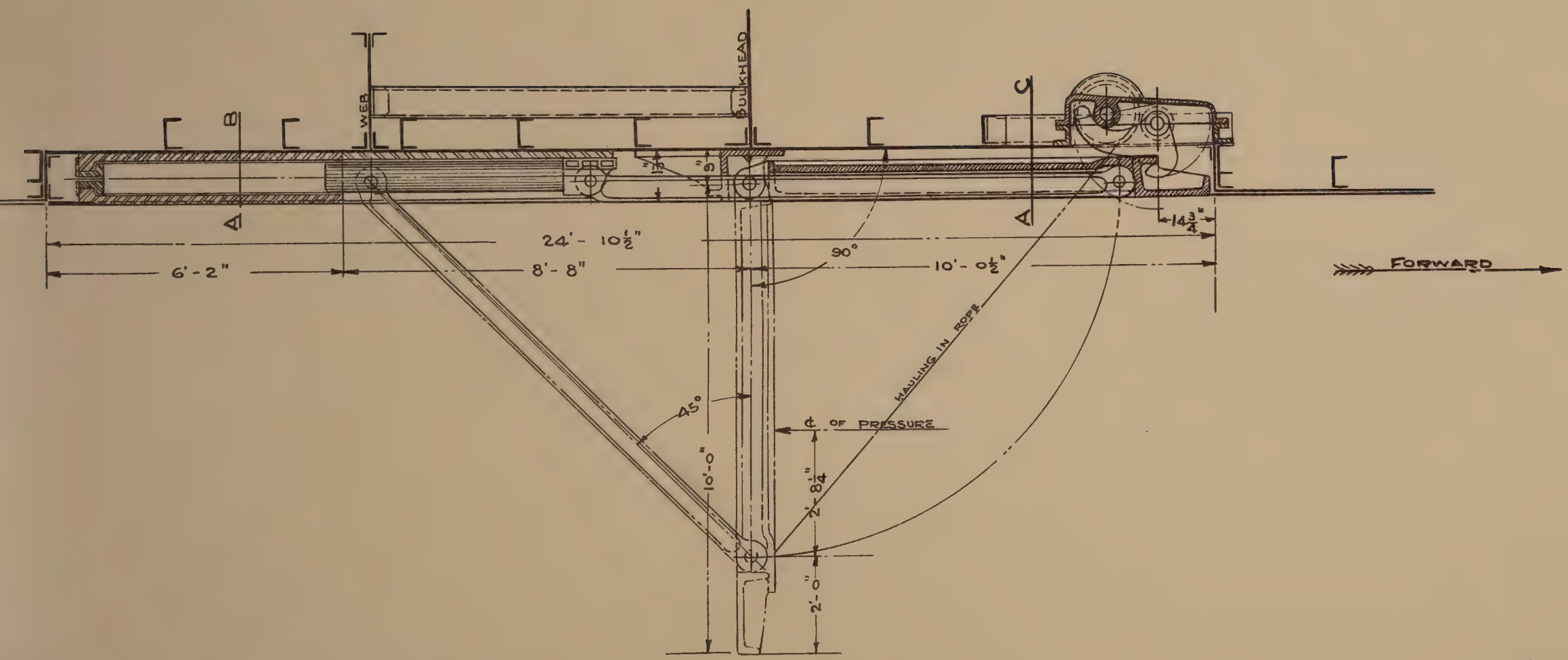
SECTION A-B

LOOKING FORWARD



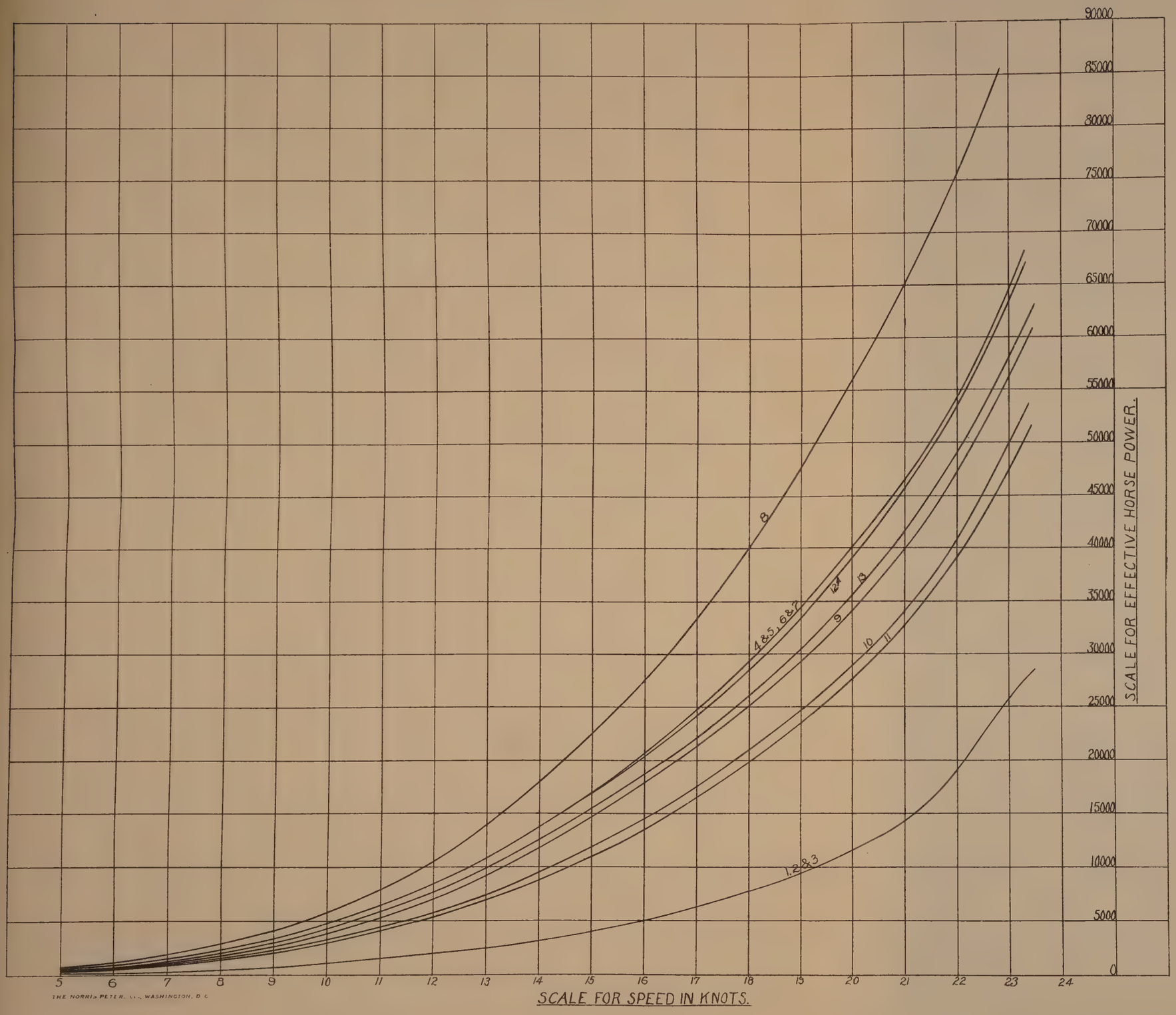
SECTION A-C

LOOKING FORWARD



THE NORRIS PETERS CO. WASHINGTON, D. C.

To illustrate paper on "Results of Model Tank Experiments to Determine the Action of a Ship Brake," by Captain William Strother Smith, U. S. N., Member.



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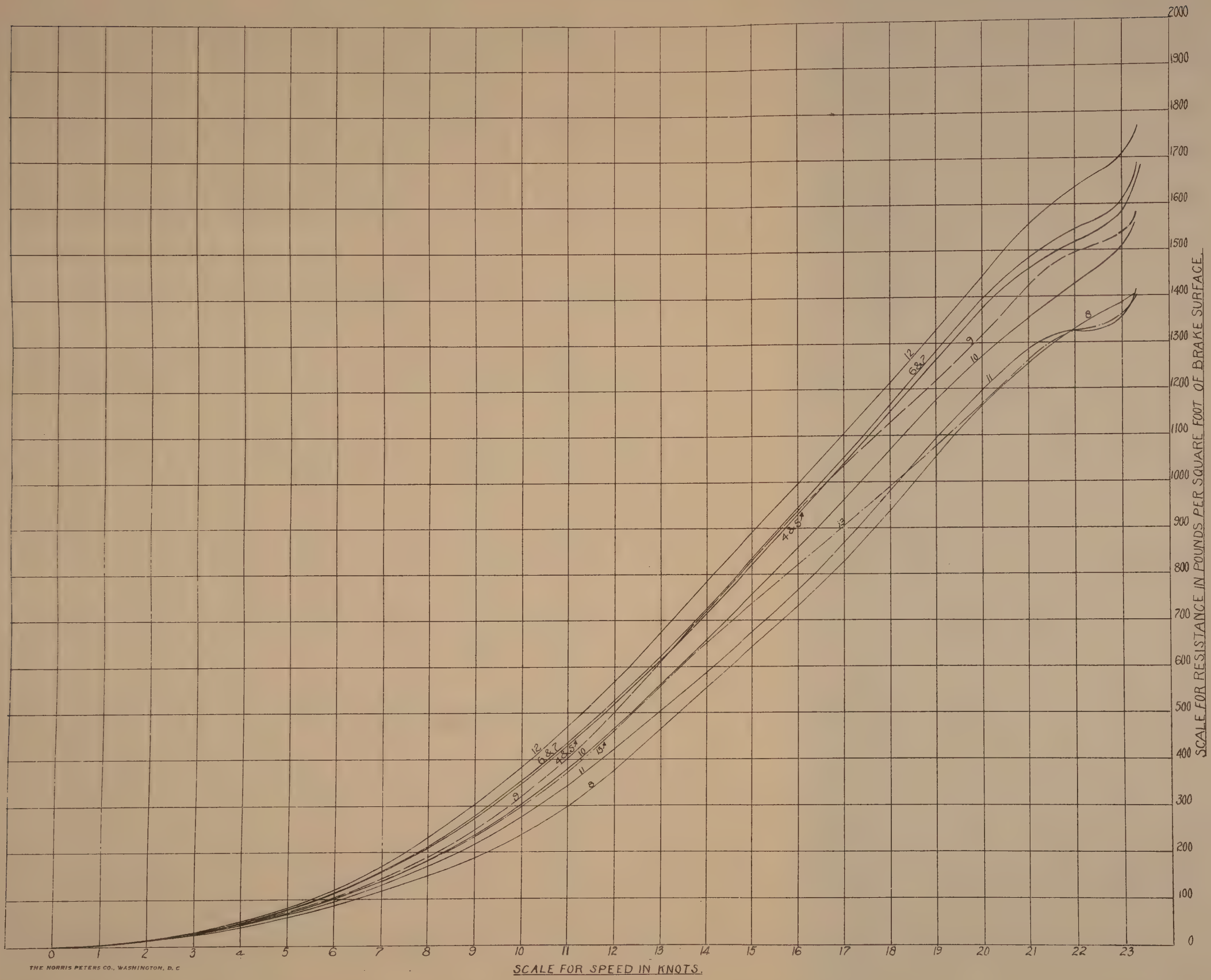

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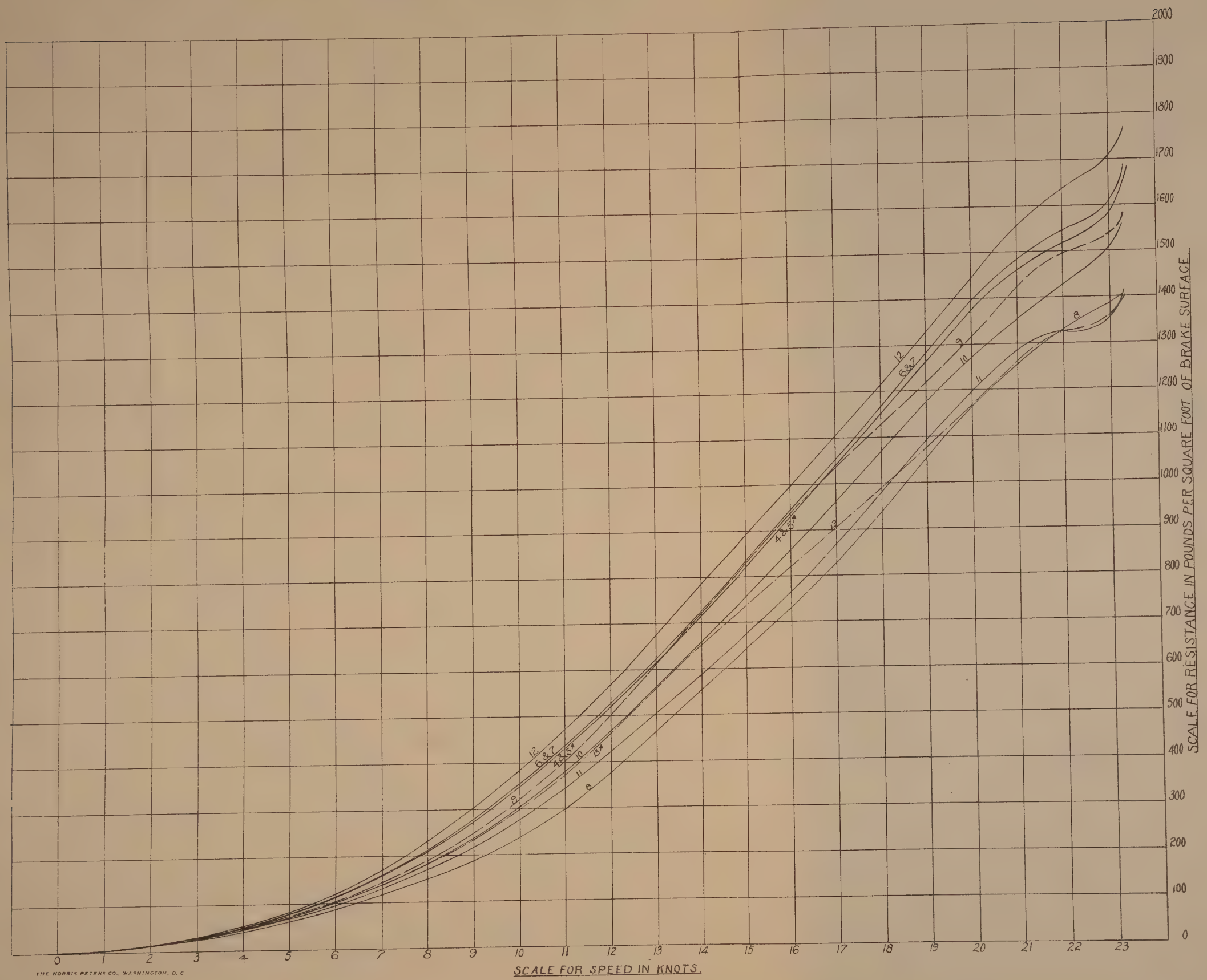

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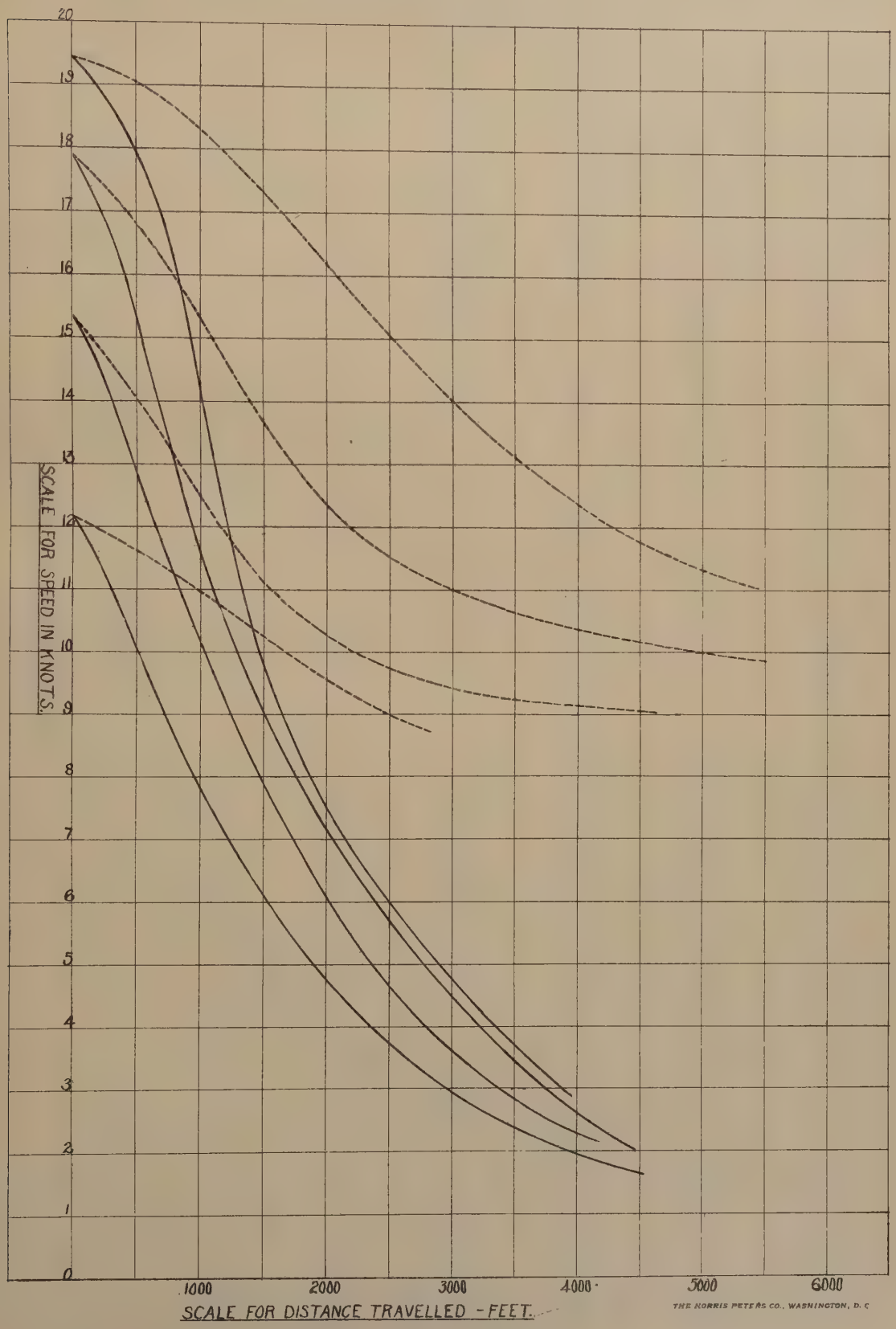

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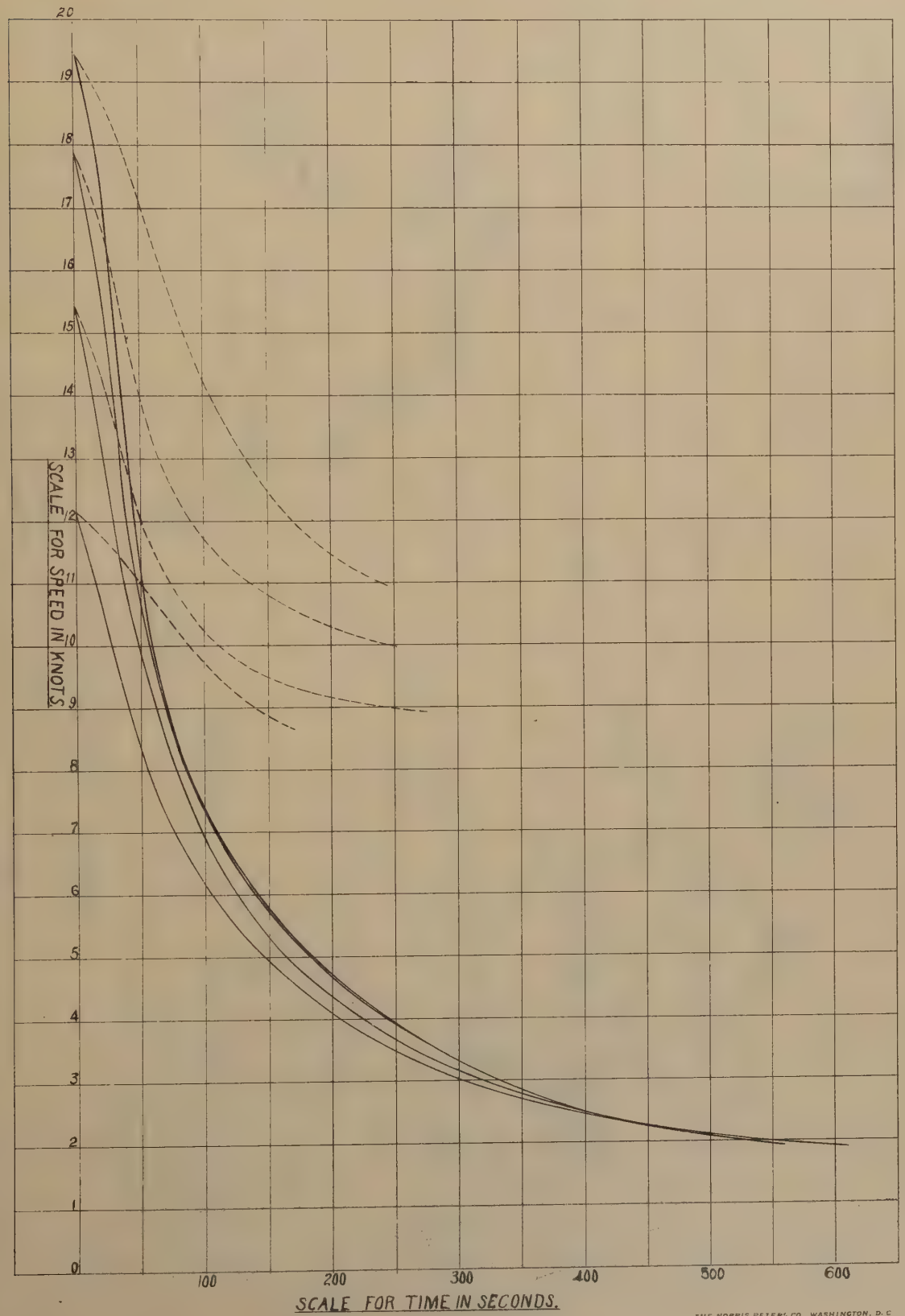
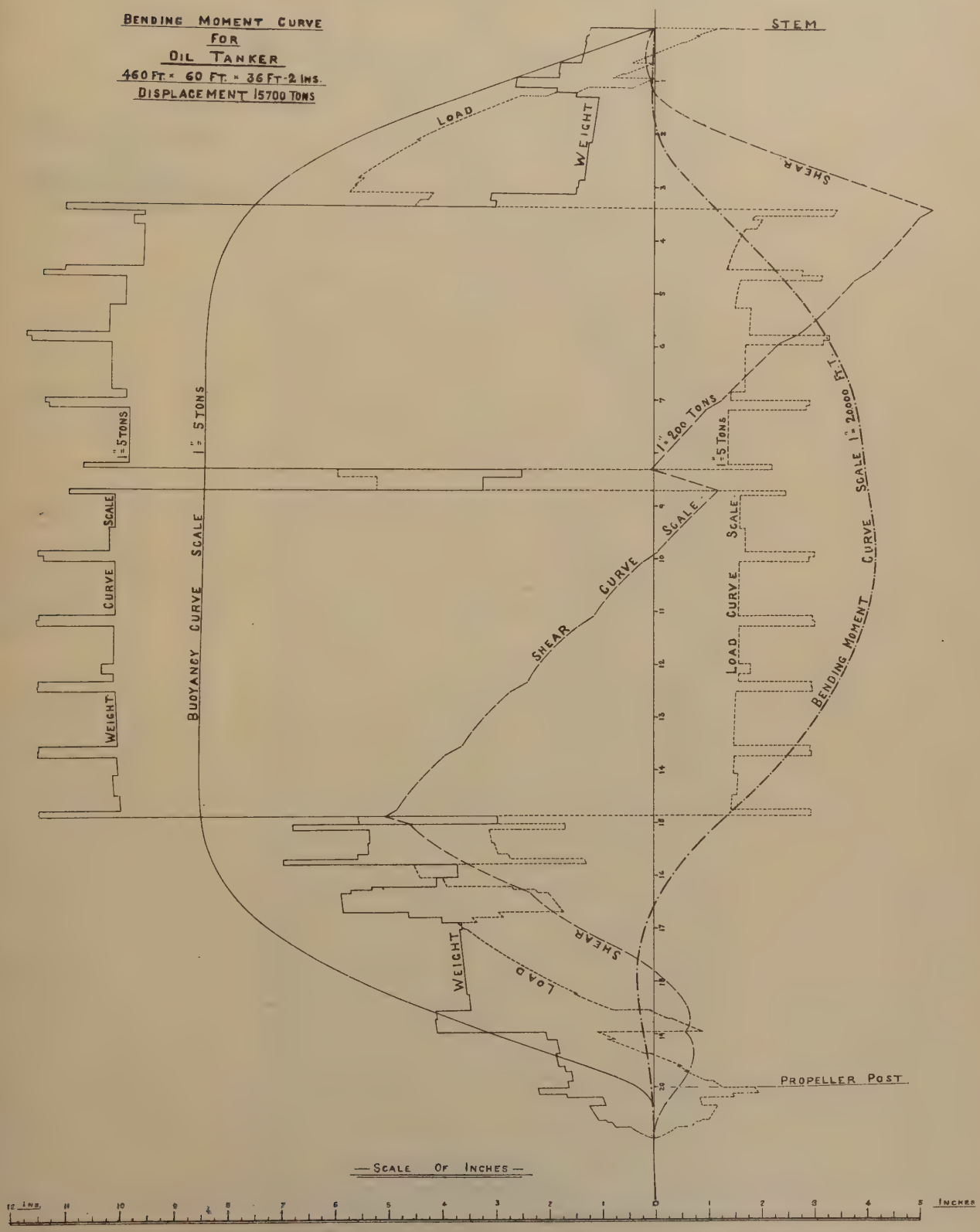


THE NORRIS PETERS CO., WASHINGTON, D. C

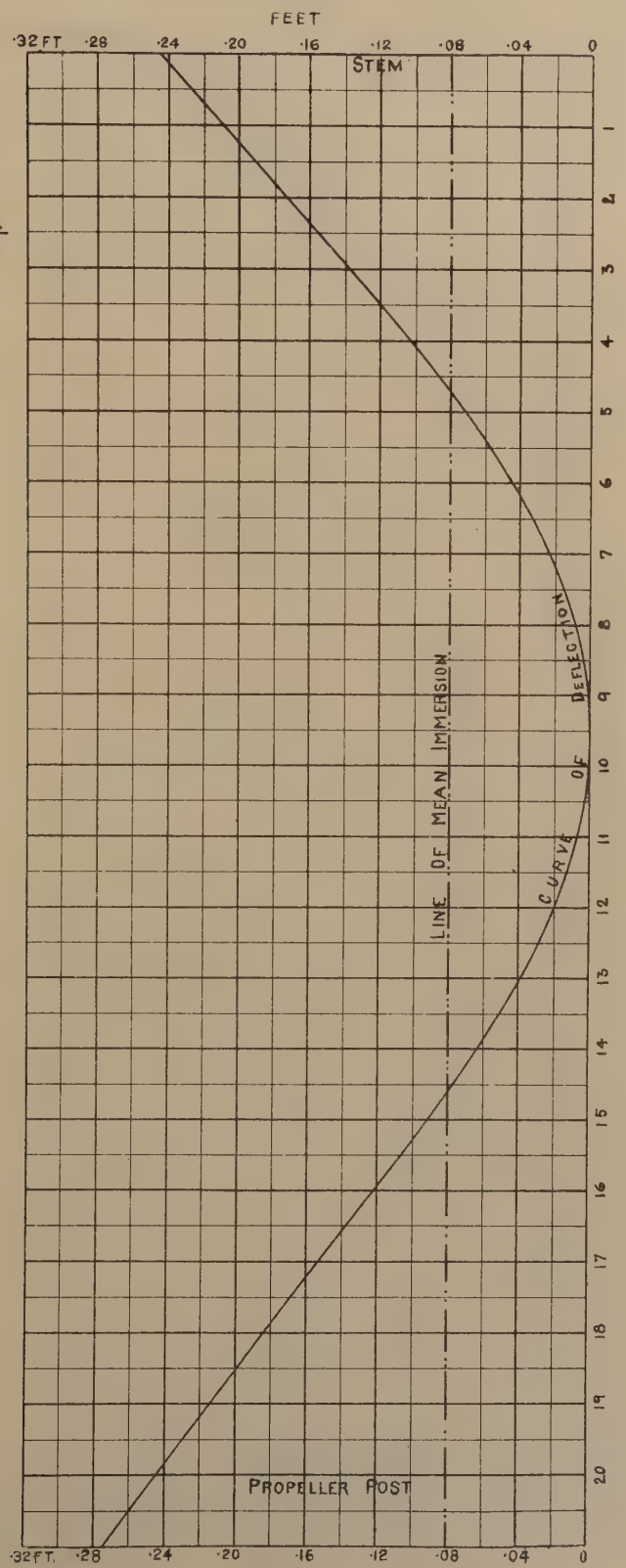
To illustrate paper on "The Maintenance of the Fleet," by Captain A. P. Niblack, U. S. N., Vice-President.

To illustrate paper on "Period of Vibration of Steam Vessels," by William Gatewood, Esq., Member.



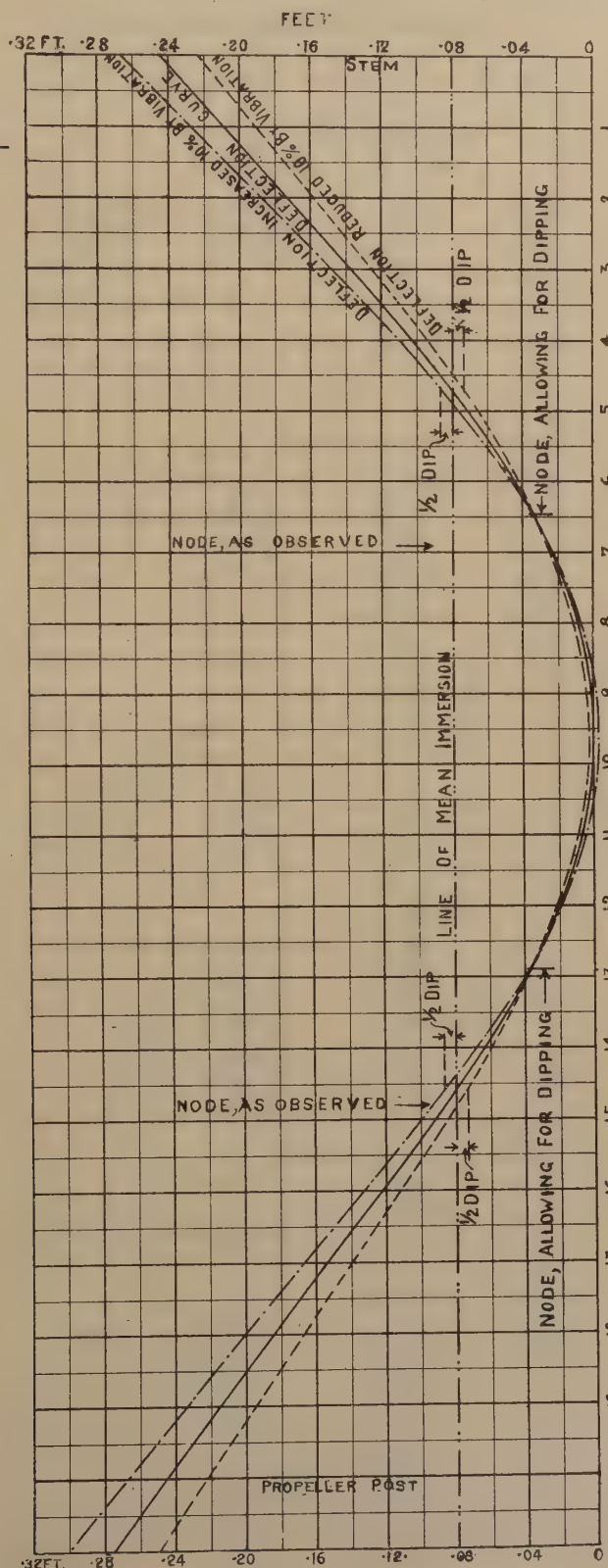
To illustrate paper on "Period of Vibration of Steam Vessels," by William Gatewood, Esq., Member.

CURVE OF DEFLECTION
FOR
OIL TANKER
460 FT. × 60 FT. × 36 FT. 2 INS.
DISPLACEMENT 15700 TONS



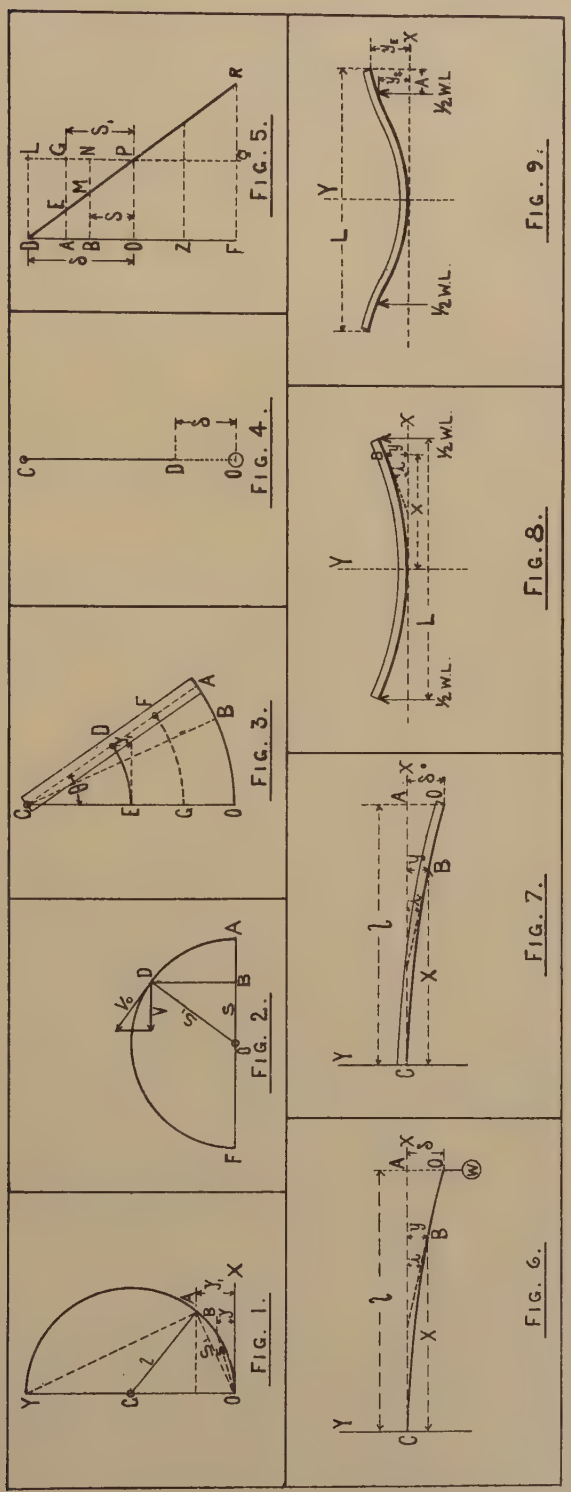
To illustrate paper on "Period of Vibration of Steam Vessels," by William Gatewood, Esq., Member.

EFFECT OF DIPPING ON VIBRATION

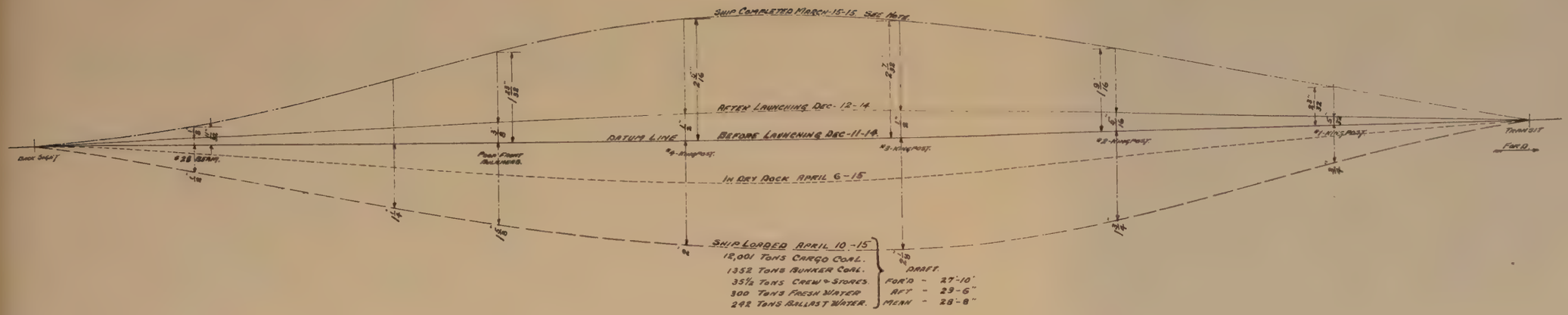

FEET
·32 FT. ·28 ·24 ·20 ·16 ·12 ·08 ·04 0
STEM
DEFLECTION INCREASED 10% BY VIBRATION
DEFLECTION REDUCED 10% BY VIBRATION
½ DIP
½ DIP
NODE, ALLOWING FOR DIPPING
NODE, AS OBSERVED
LINE OF MEAN IMMERSION
½ DIP
NODE, AS OBSERVED
½ DIP
NODE, ALLOWING FOR DIPPING
PROPELLER POST
·32 FT. ·28 ·24 ·20 ·16 ·12 ·08 ·04 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

To illustrate paper on "Period of Vibration of Steam Vessels," by William Gatewood, Esq., Member.

DIAGRAMS ILLUSTRATING APPENDIX



To illustrate paper on "Data on Hog and Sag of Merchant Vessels," by T. M. Cornbrooks, Esq., Member.

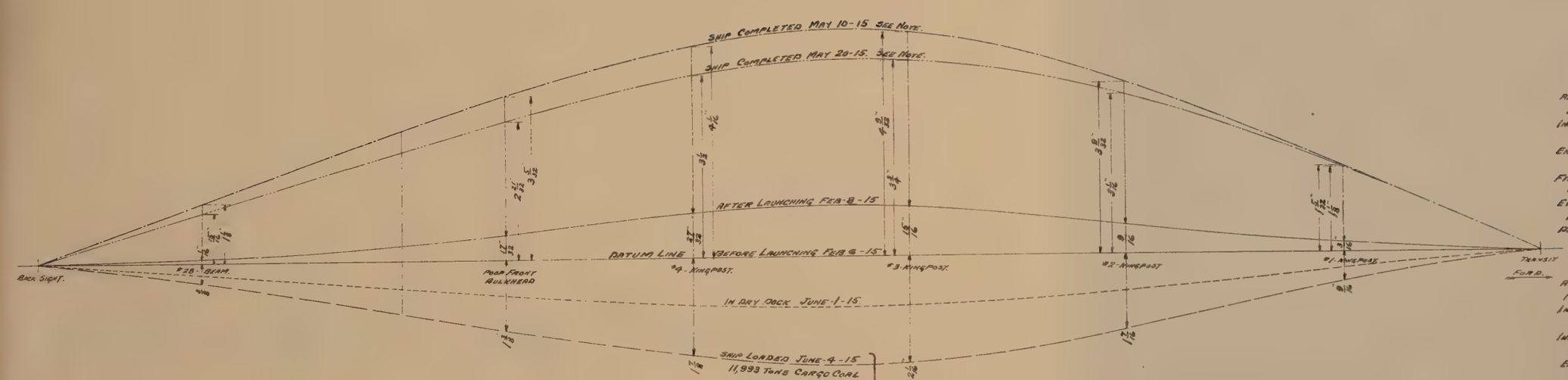


NOTE:-
SHIP COMPLETED MARCH 15TH 1915
TOPSIDE TANKS EMPTY.
DEEP TANKS FOR'D EMPTY.
FOR'D PEAK TANK EMPTY.
INNER BOTTOMS 1 TO 4 INCLUSIVE } 735 84 TONS.
OF CARGO HOLDS FULL
INNER BOTTOMS 5 TO 8 INCLUSIVE }
OF CARGO HOLDS EMPTY
ENGINE ROOM INNER BOTTOM STARB'D SIDE 7.77 TONS.
" " " " PORT " 15.64 "
FIRE " " " STARB'D " 6.19 "
" " " " PORT " EMPTY.
WATER IN BOILERS STEAMING LEVEL.
AFTER PEAK TANK EMPTY.
DOMESTIC TANK FULL (FRESH WATER) 20 TONS
DRAFT:- FOR'D 9'-9½ AFT. 17'-7¾" MEAN 11'-8½.

BENCH SIGHTS.

PANAMA COLLIER "ULYSSES"

HORIZONTAL SCALE 1/16TH = 1FT.
VERTICAL SCALE FULL SIZE.



NOTE:-
SHIP COMPLETED MAY 10TH 1915.
TOPSIDE TANKS EMPTY.
ALL FOUR DEEP TANKS FOR'D FULL 1204 TONS.
FOR'D PEAK TANK FULL 307 TONS.
INNER BOTTOMS 1 TO 8 INCLUSIVE } 1576 TONS.
OF CARGO HOLDS FULL
ENGINE ROOM INNER BOTTOM STARB'D SIDE 52 TONS.
" " " " PORT " 90 "
FIRE " " " STARB'D " 20 "
" " " " PORT " 48 "
EXCESS WATER IN BOILERS. 42 "
AFTER PEAK TANK EMPTY.
DRAFT:- FOR'D 15-6" AFT 14'-7" MEAN 15'-1"

SHIP COMPLETED MAY 20TH 1915.
TOPSIDE TANKS EMPTY.
ALL FOUR DEEP TANKS FOR'D 1083 TONS.
FOR'D PEAK TANK 172 "
INNER BOTTOMS 1 & 2 INCLUSIVE } 342 "
OF CARGO HOLDS FULL
INNER BOTTOMS 3 TO 8 INCLUSIVE
OF CARGO HOLDS EMPTY
ENGINE ROOM INNER BOTTOM STARB'D SIDE 40 TONS
" " " " PORT " 75 "
FIRE " " " STARB'D " 77 "
" " " " PORT " 38
WATER IN BOILERS STEAMING LEVEL
AFTER PEAK TANK EMPTY
DRAFT:- FOR'D 11-3" AFT 14'-11½ MEAN 13'-1¾"

BENCH SIGHTS.

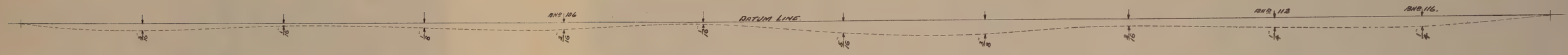
PANAMA COLLIER "ACHILLES."

HORIZONTAL SCALE 1/16TH = 1FT.
VERTICAL SCALE FULL SIZE.

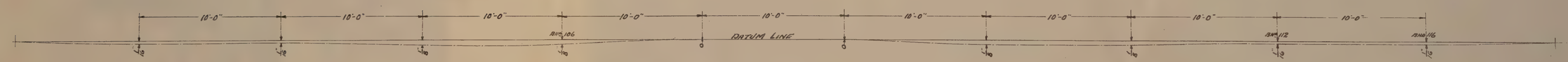
THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Data on Hog and Sag of Merchant Vessels,"
by T. M. Cornbrooks, Esq., Member.

DECEMBER 29TH 1915 TANKS #1 & 4 FULL = 793 TONS WATER.



JANUARY 4TH 1915 TANKS #1 & 4 FULL = 793 TONS WATER

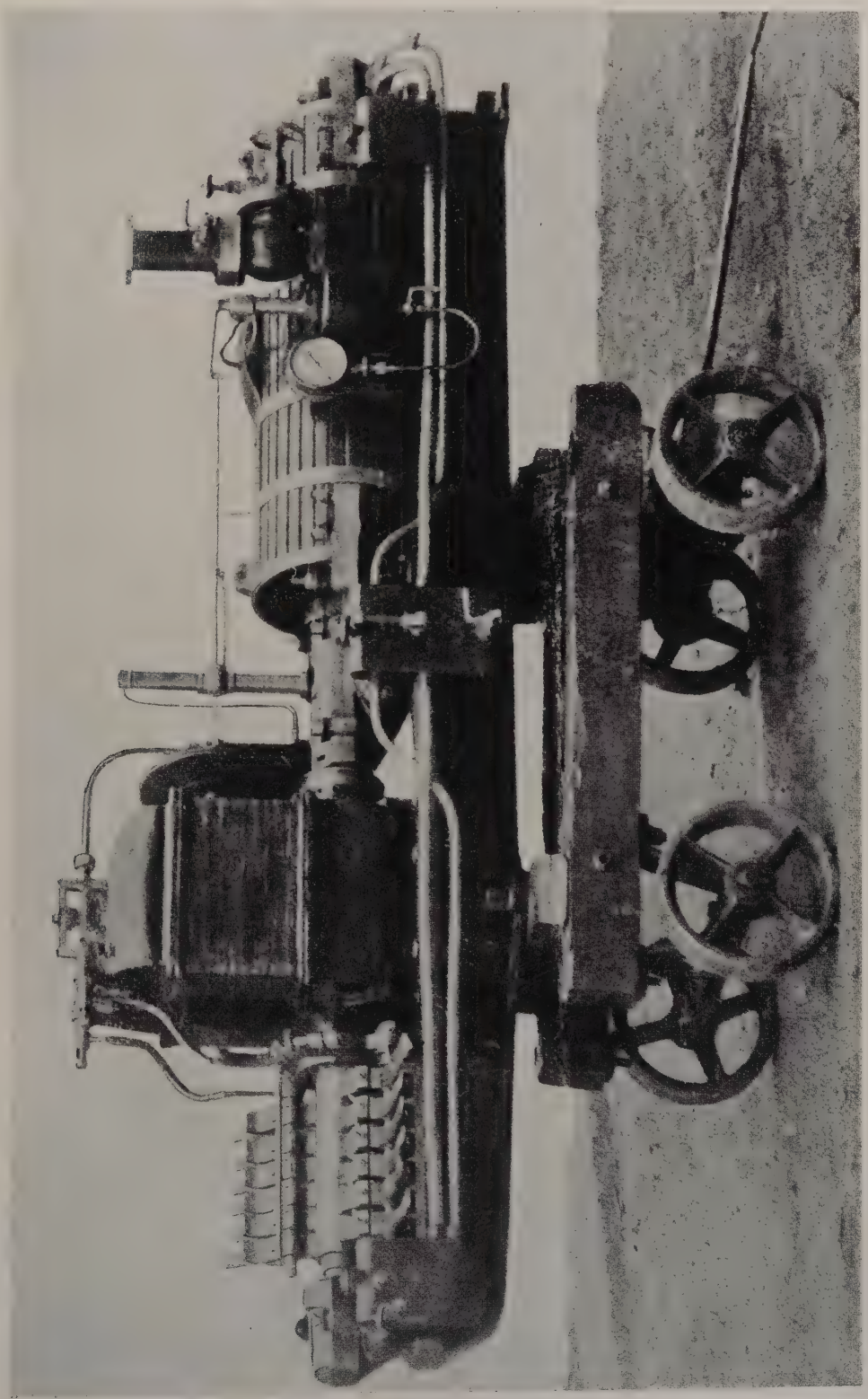


JANUARY 14TH 1915 TANKS EMPTY.

NOTE:-
DEFLECTION TAKEN ON UNDER SIDE OF SHIP.
HORIZONTAL SCALE $\frac{3}{8}$ IN. = 1 FT.
VERTICAL SCALE FULL SIZE.

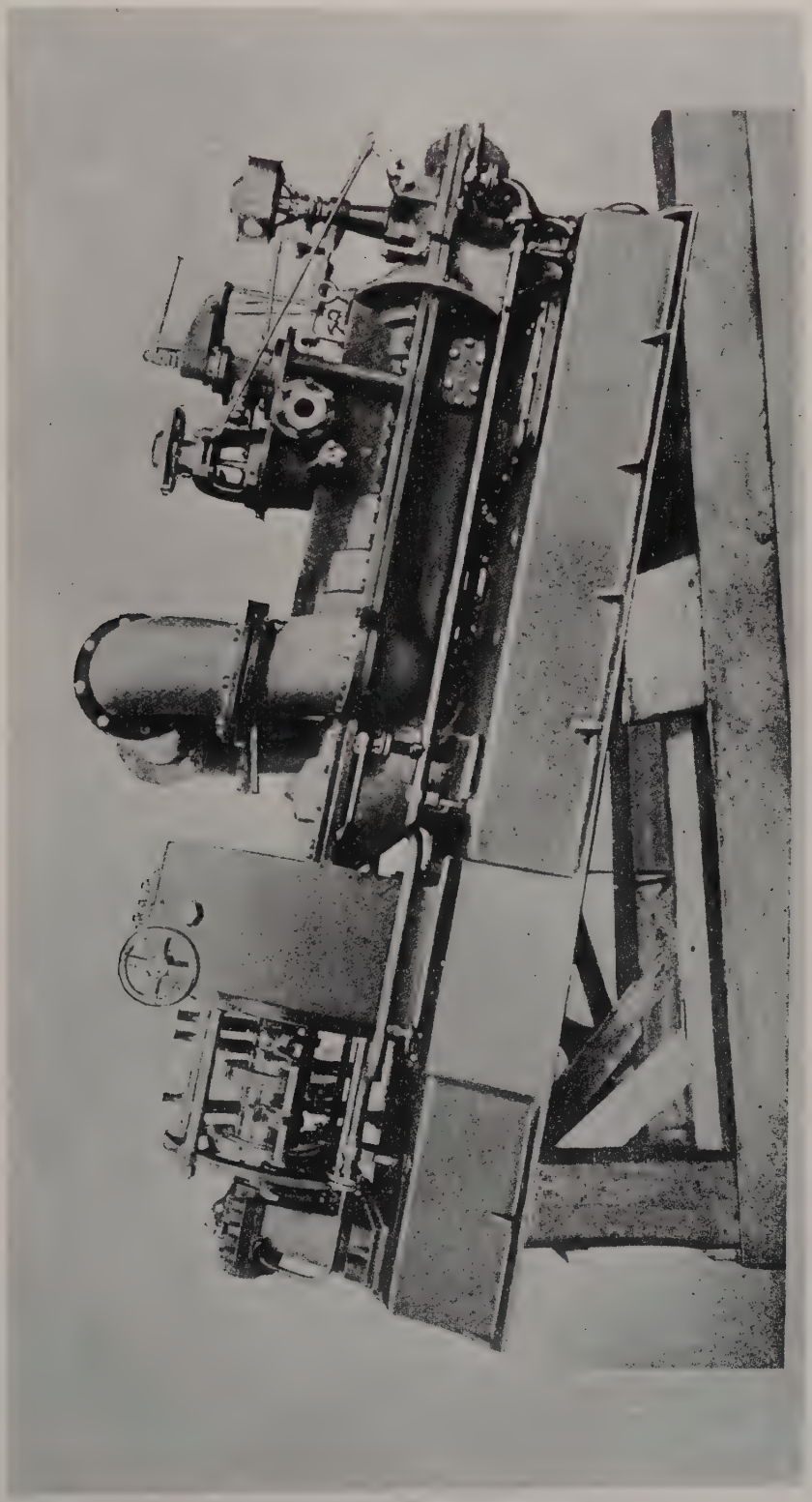
THE HORRIS PETERS CO. WASHINGTON, D. C

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



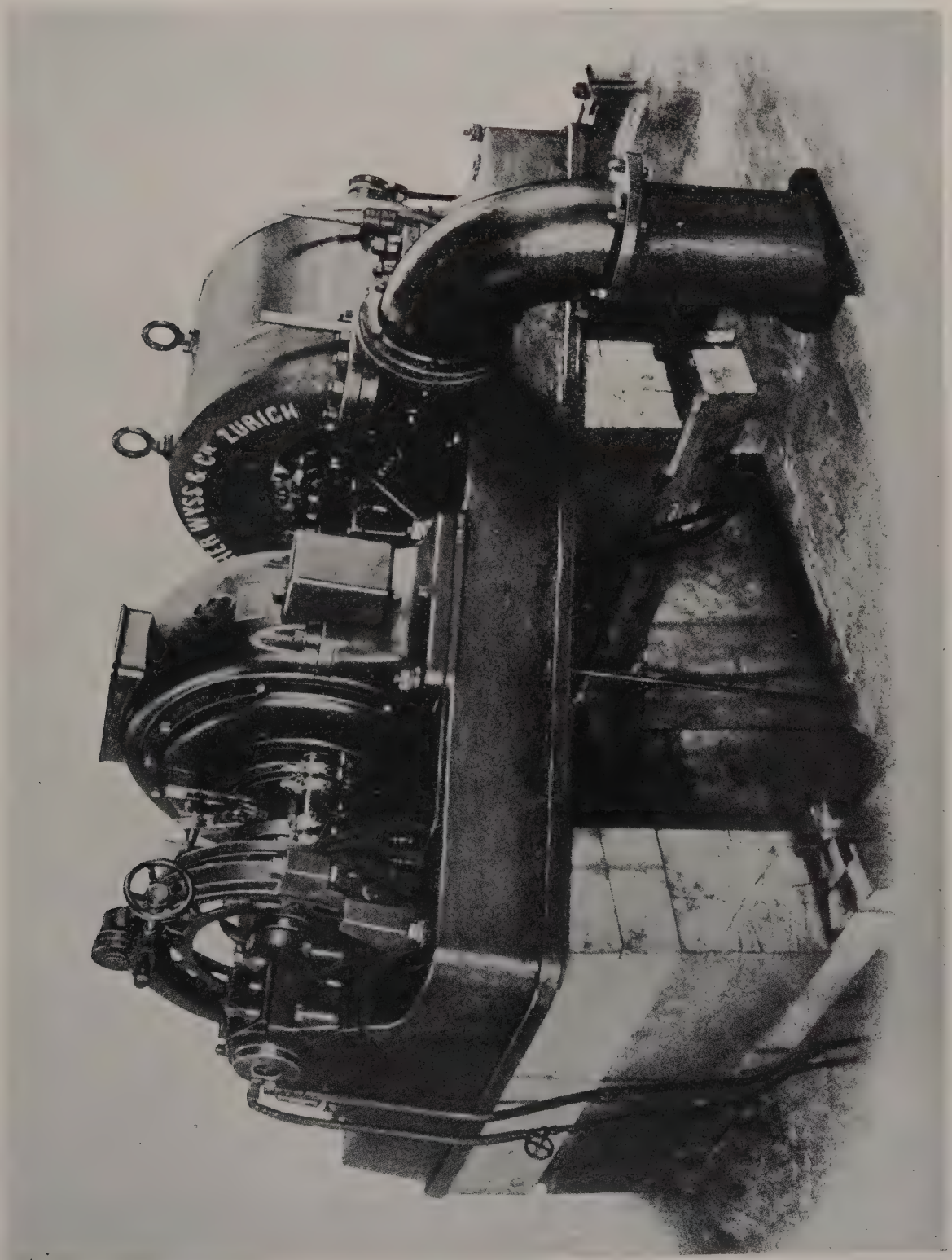
Early Parsons' Double Flow Turbine for Ship Lighting. About 1887.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



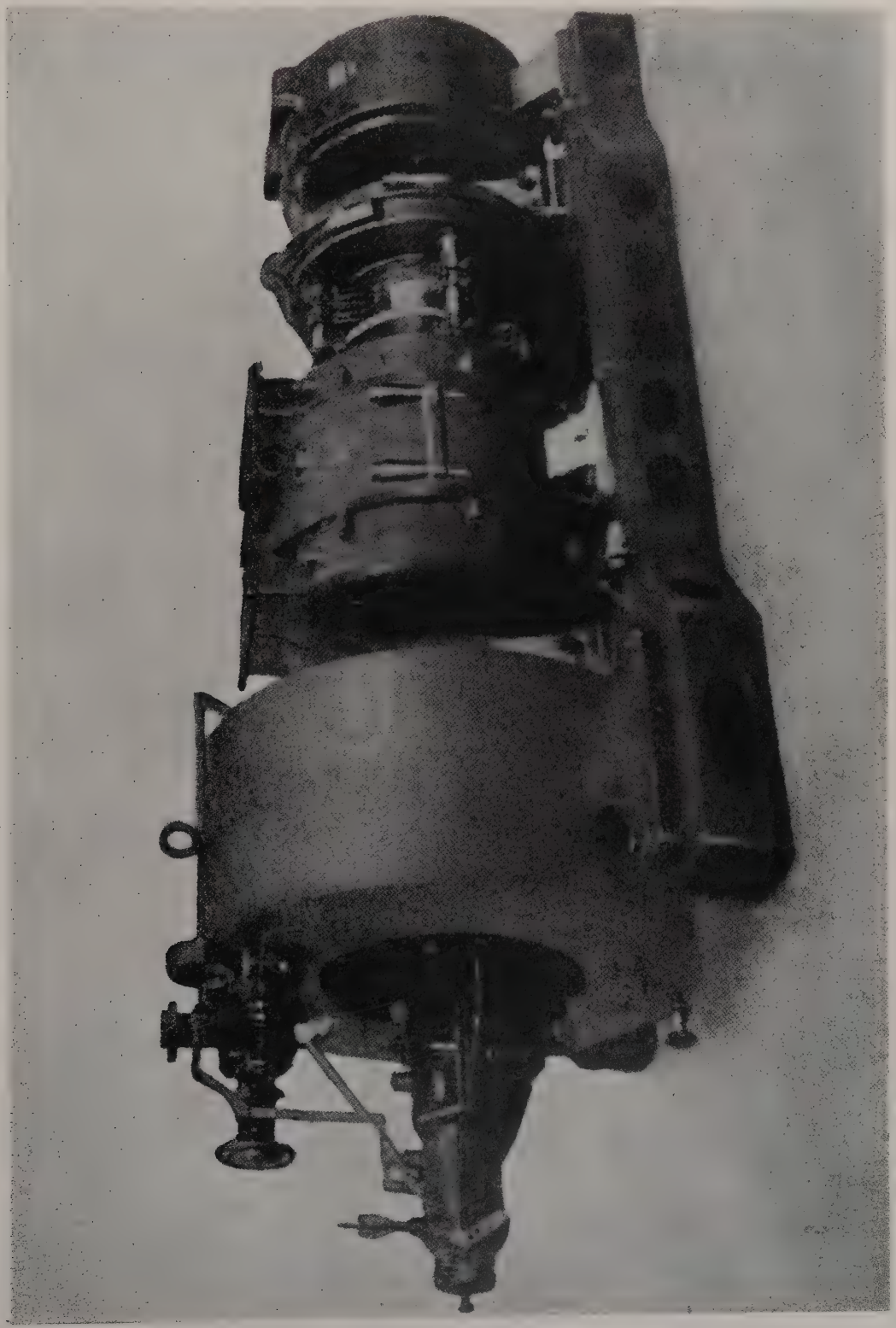
SEVENTY-FIVE K.W. BROWN-BOVERI LIGHTING SET, USED IN GERMAN AND FRENCH NAVIES.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



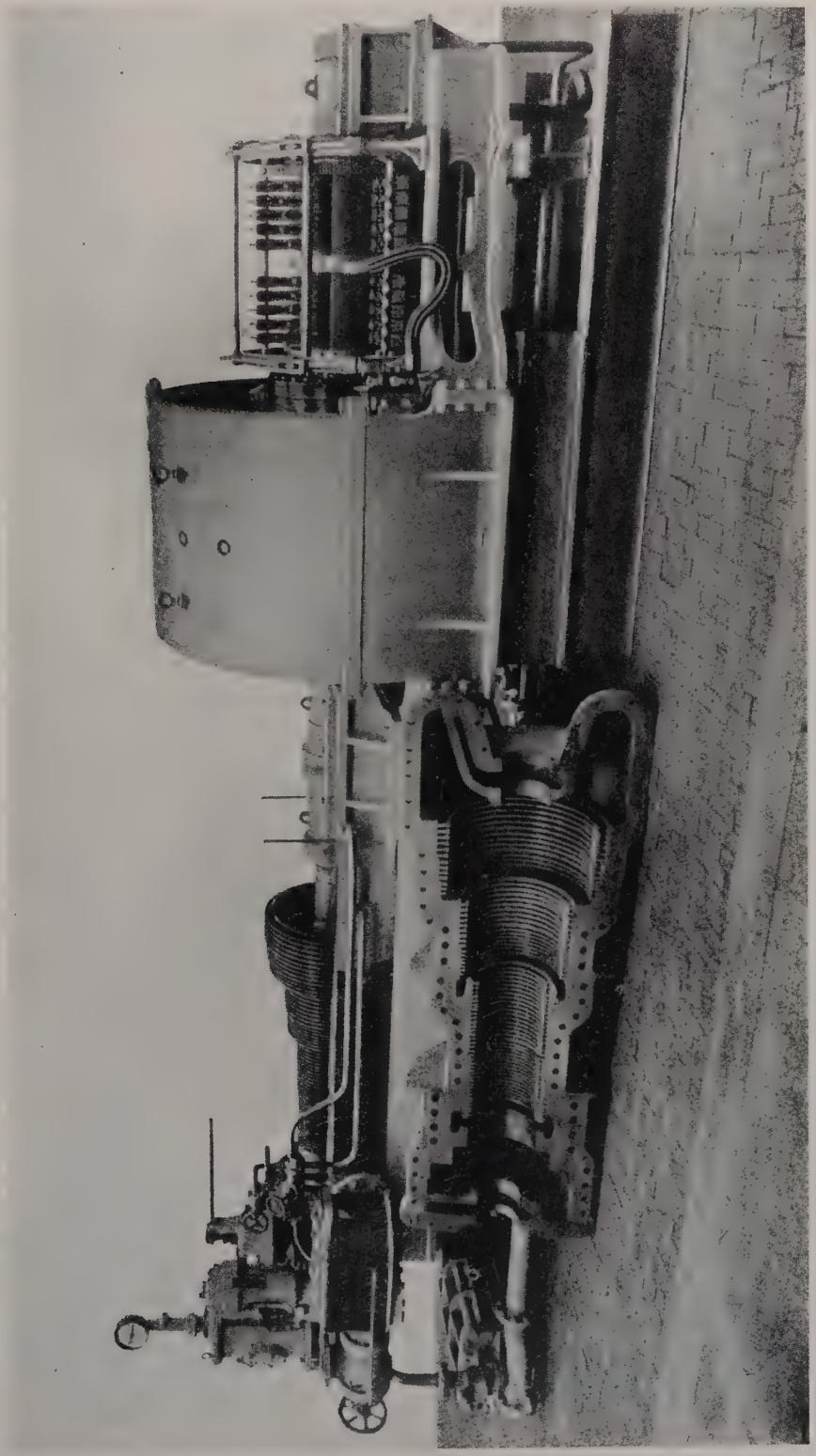
SEVENTY-FIVE K.W. ESCHER-WEISS (ZOELLY TYPE) LIGHTING SET USED IN GERMAN AND FRENCH MARINE.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



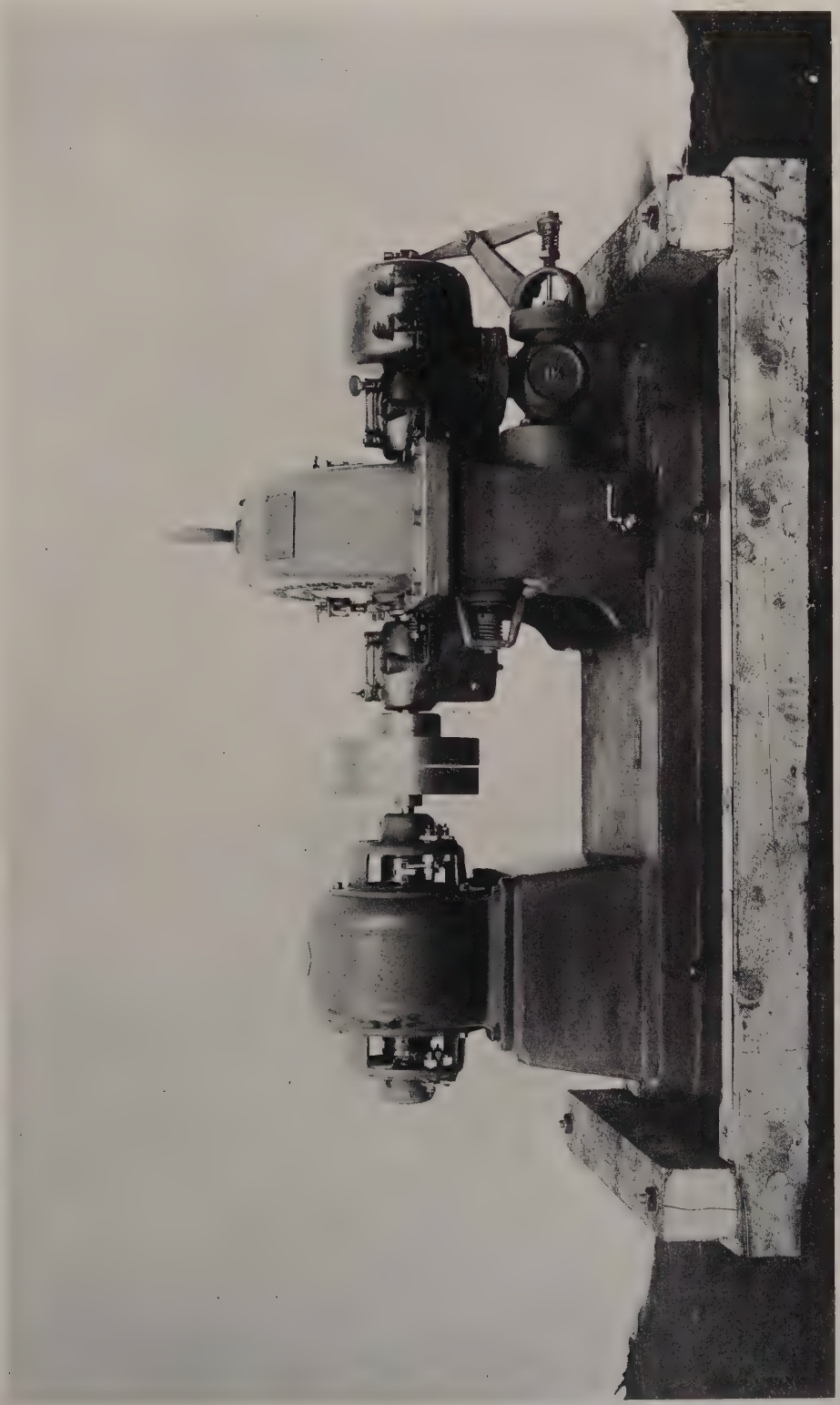
Mellons Pfenneiger German Naval Type of Lighting Set.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



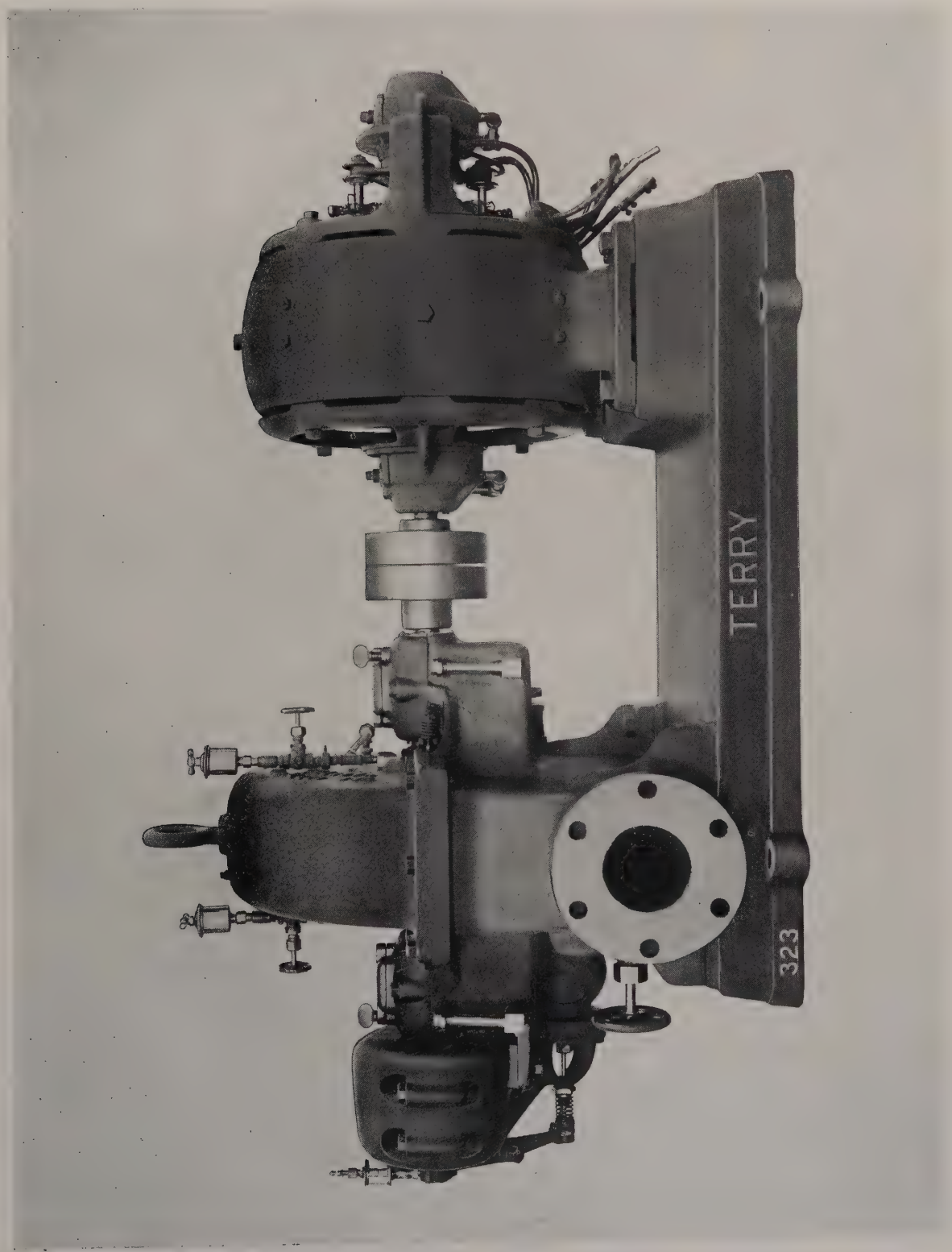
THREE HUNDRED AND SEVENTY-FIVE K.W. TURBO-GENERATOR BUILT BY C. A. PARSONS & CO. FOR R. M. S. MAURETANIA.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



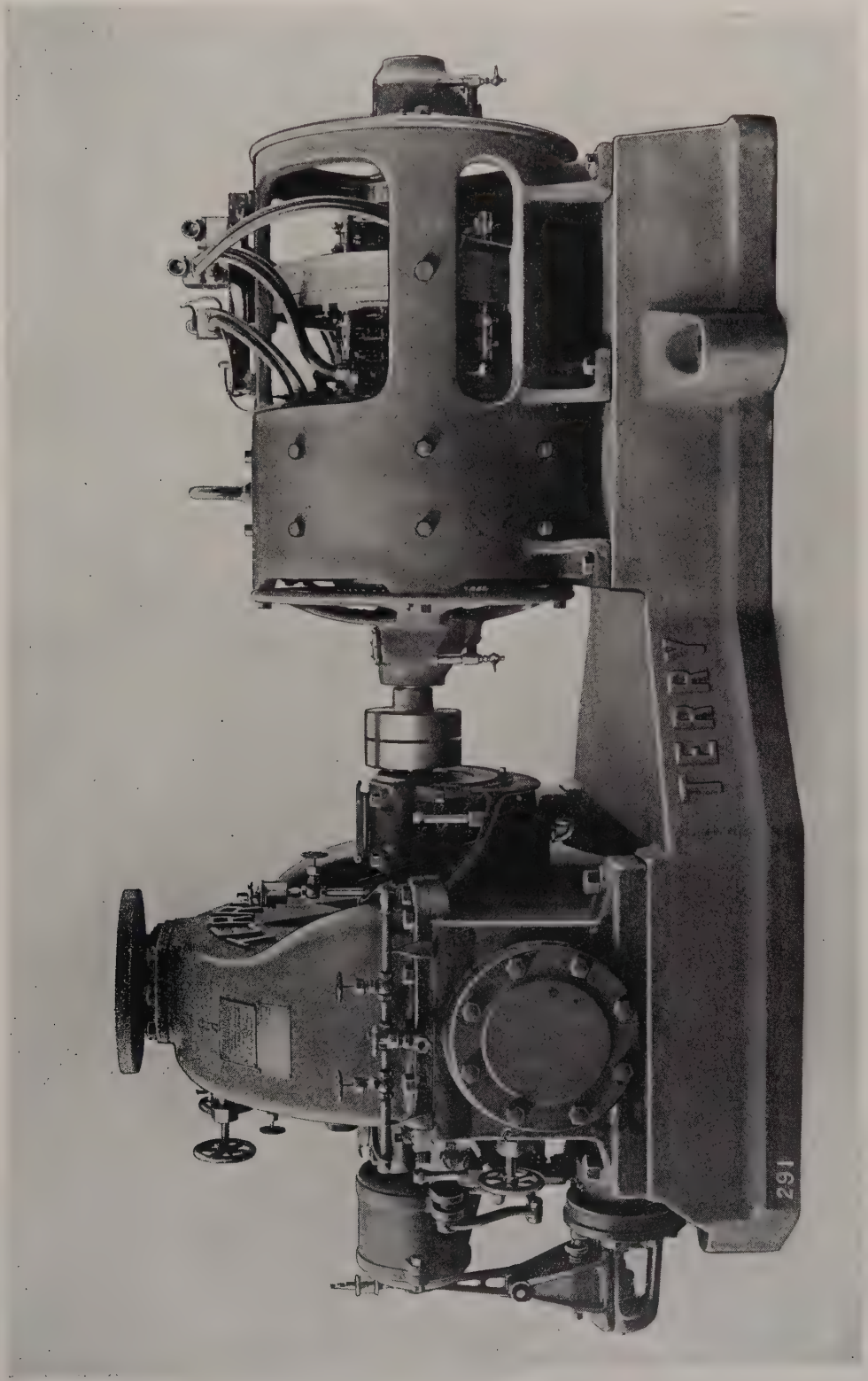
TERRY WIRELESS-TELEGRAPH SET.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



Ten k.w. Standard Terry Marine Lighting Set.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



THIRTY-FIVE K.W. TERRY MARINE LIGHTING SET.

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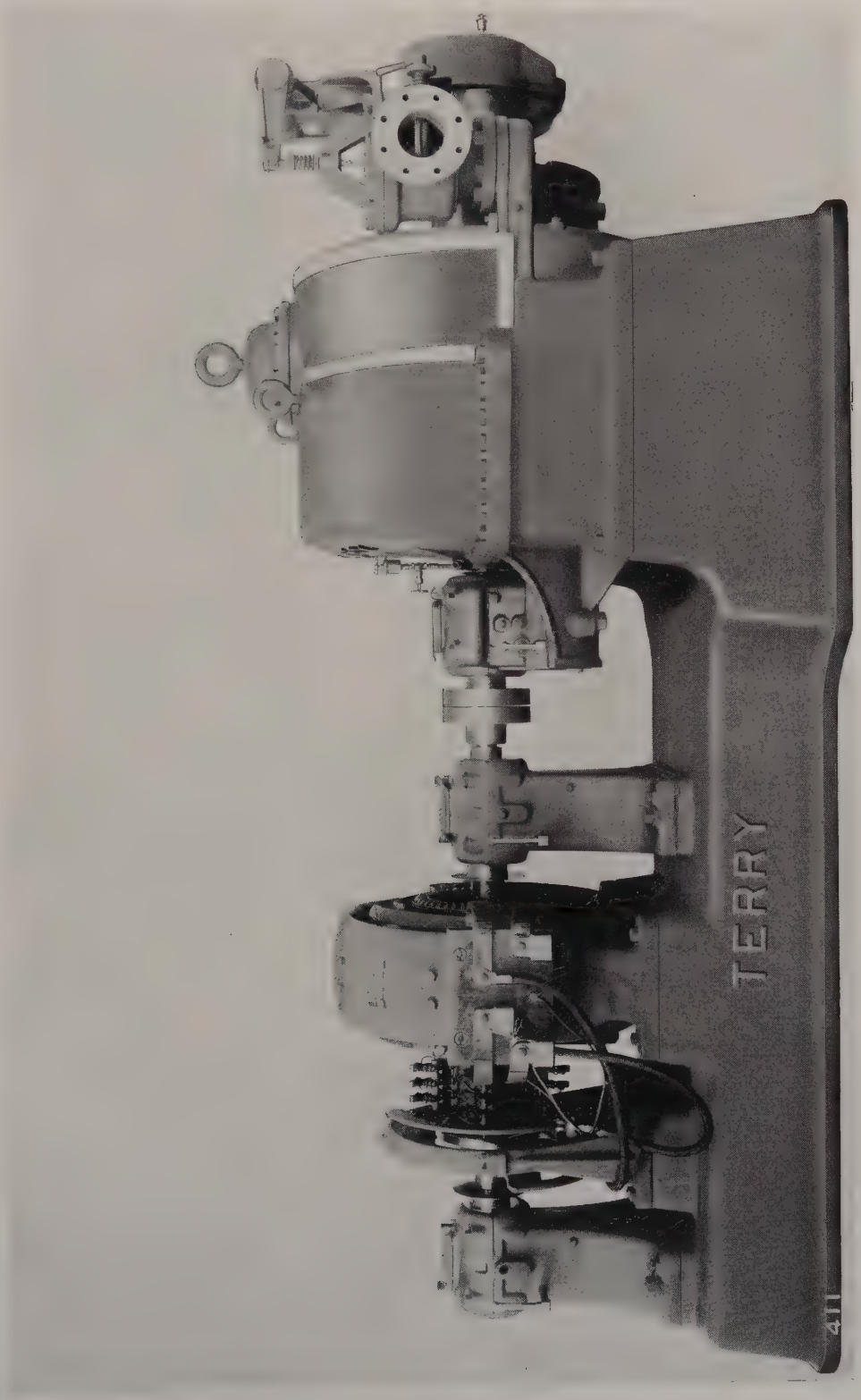

TYPE G F CONDENSING TURBO-GENERATOR SET.

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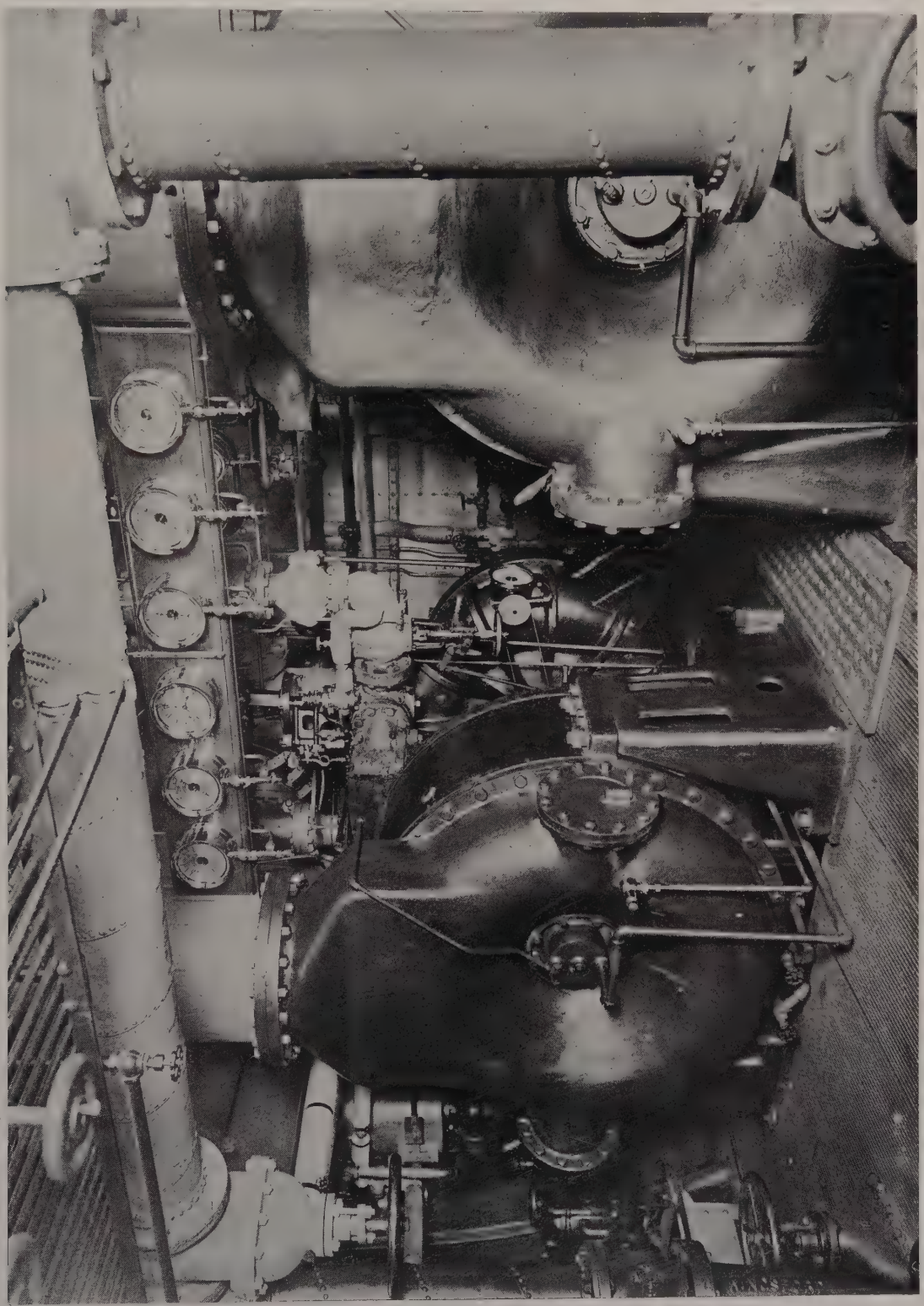
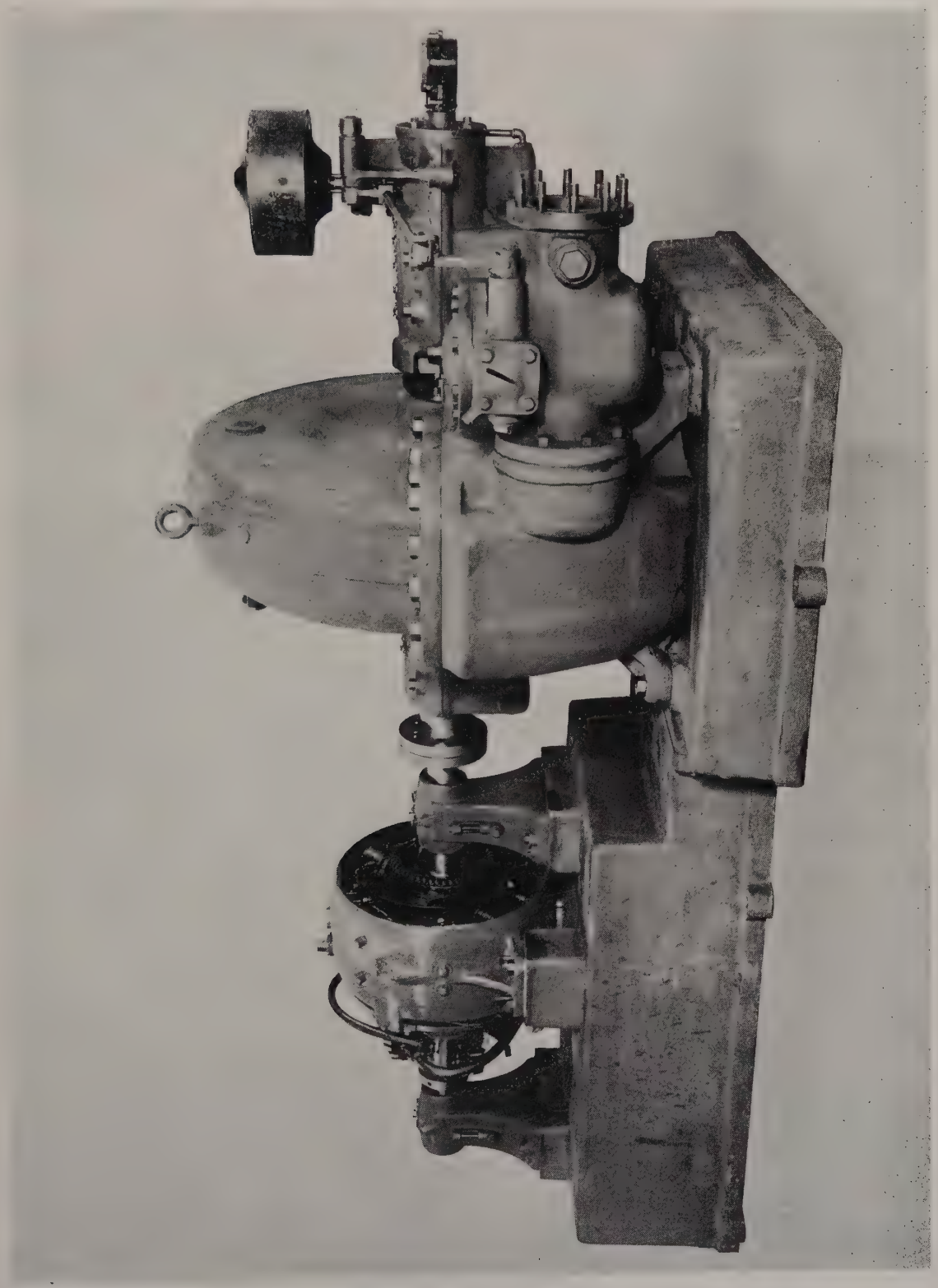


CURTIS TURBINE DRIVING WORTHINGTON PUMPS ON THE FIRE-BOAT DELUGE, CITY OF BALTIMORE.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.

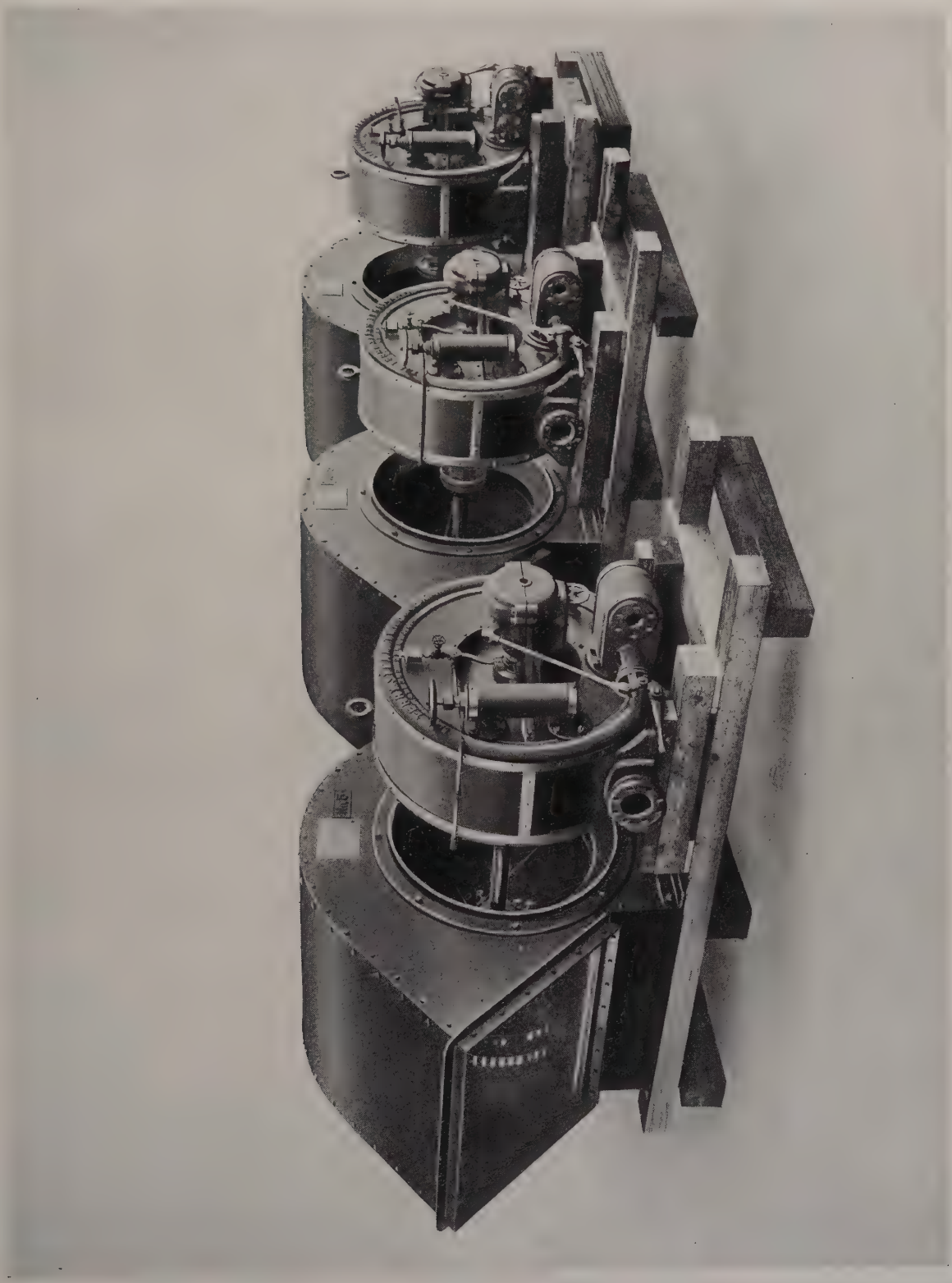


De Laval Marine Lighting Set.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.

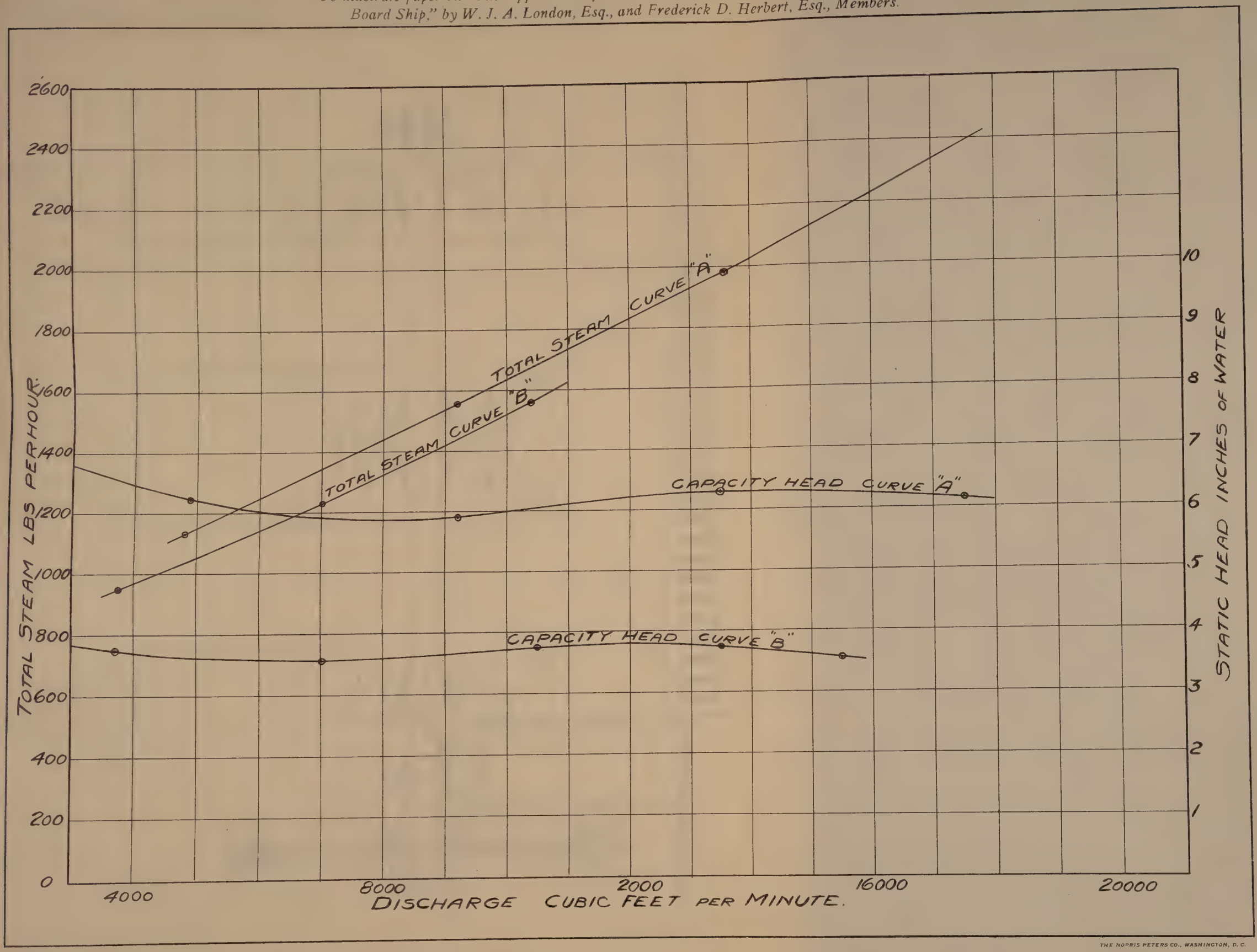
ORIGINAL 3-BEARING VERTICAL TERRY TURBINE, SWING OPEN.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



HORIZONTAL MARINE FORCED-DRAFT SET.

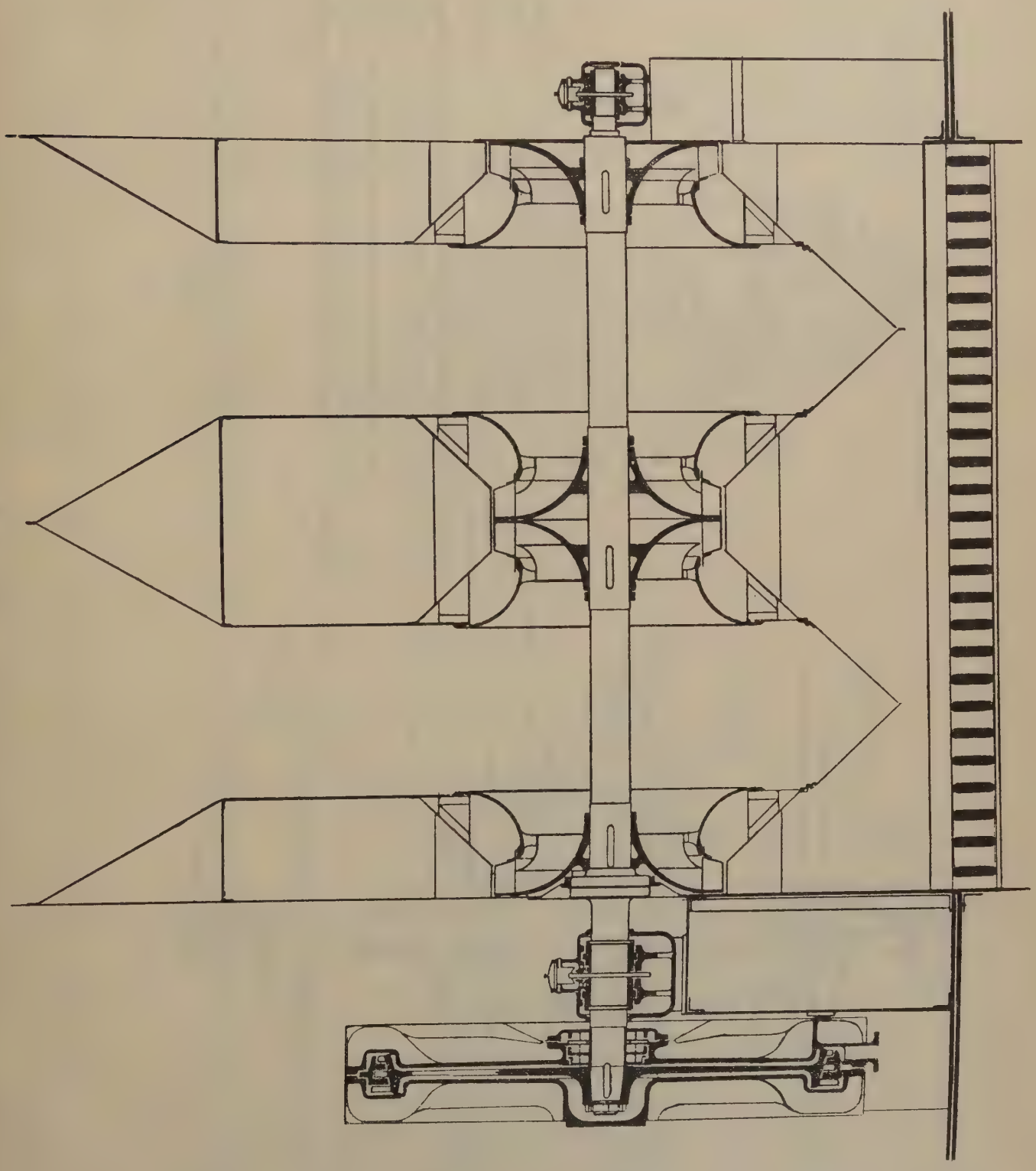
To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



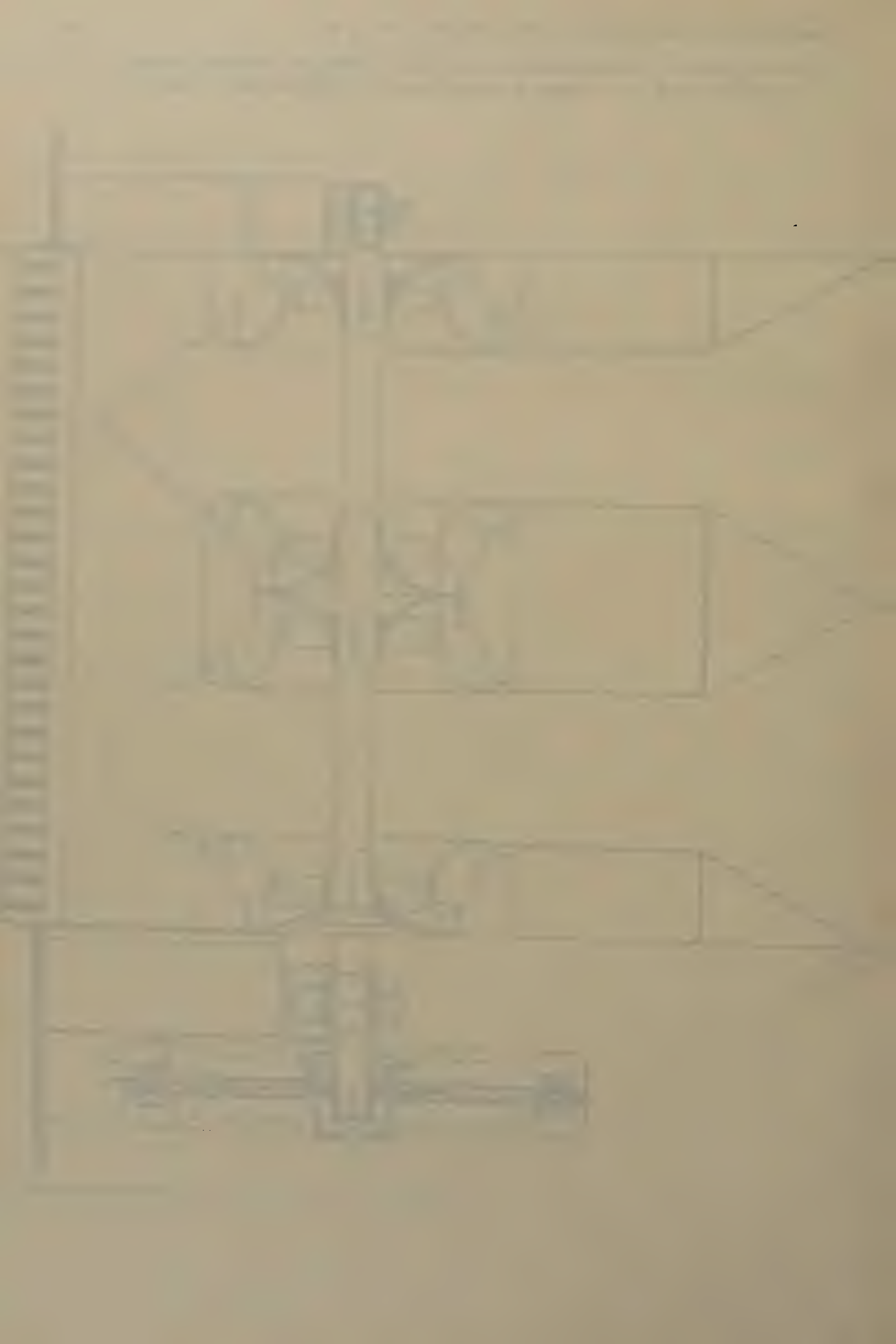
THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.

40,000 cubic ft. of air per min. at a pressure of 3½ in. water.

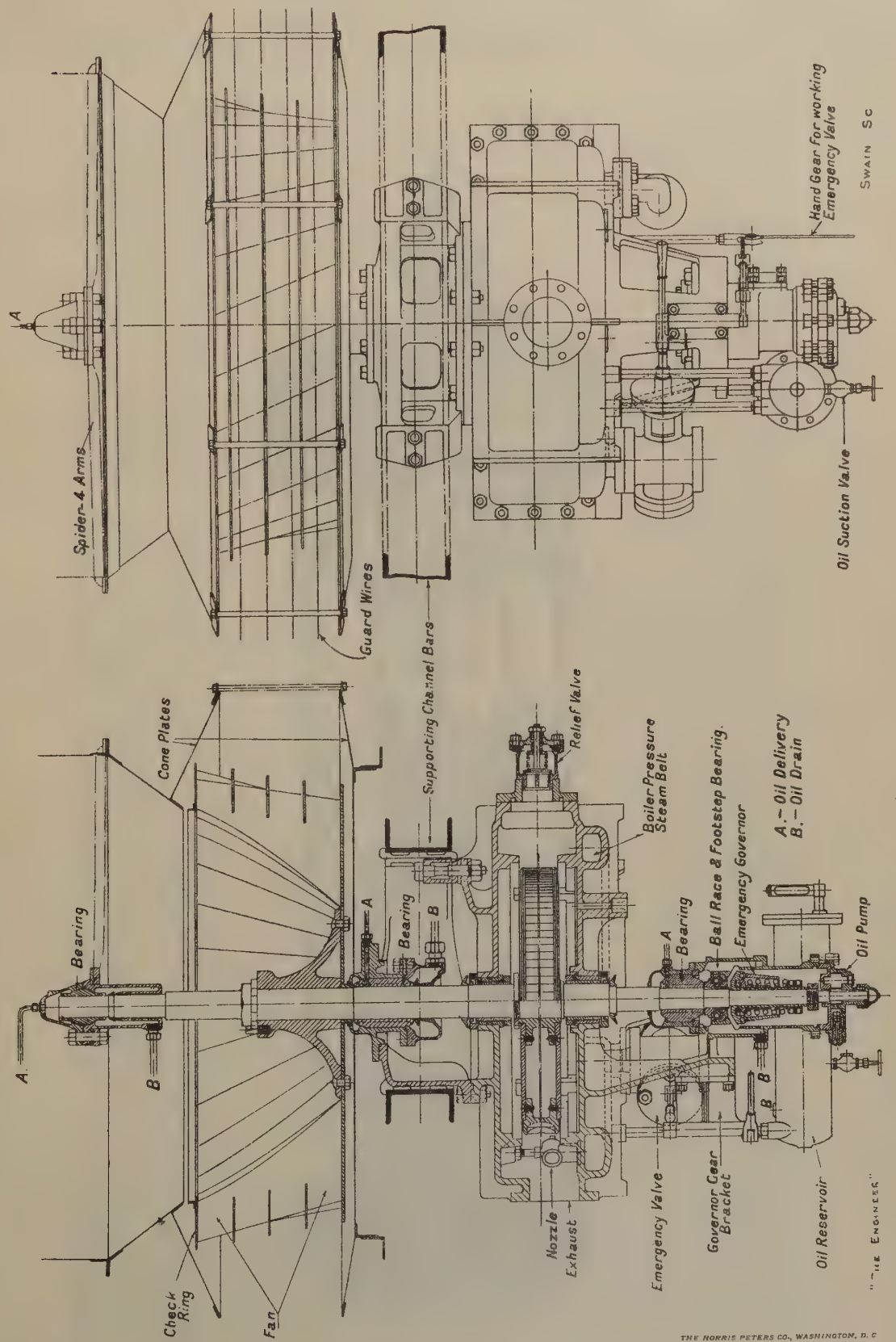


THE NORRIS PETERS CO., WASHINGTON, D. C.



To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.

YARROW-TERRY FORCED DRAUGHT TURBO-FAN



THE NORRIS PETERS CO., WASHINGTON, D. C

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.

Special Vertical Turbine Boiler Feed Pump for Marine Use.

Transactions Society Naval Architects and Marine Engineers, Vol. 23, 1915.

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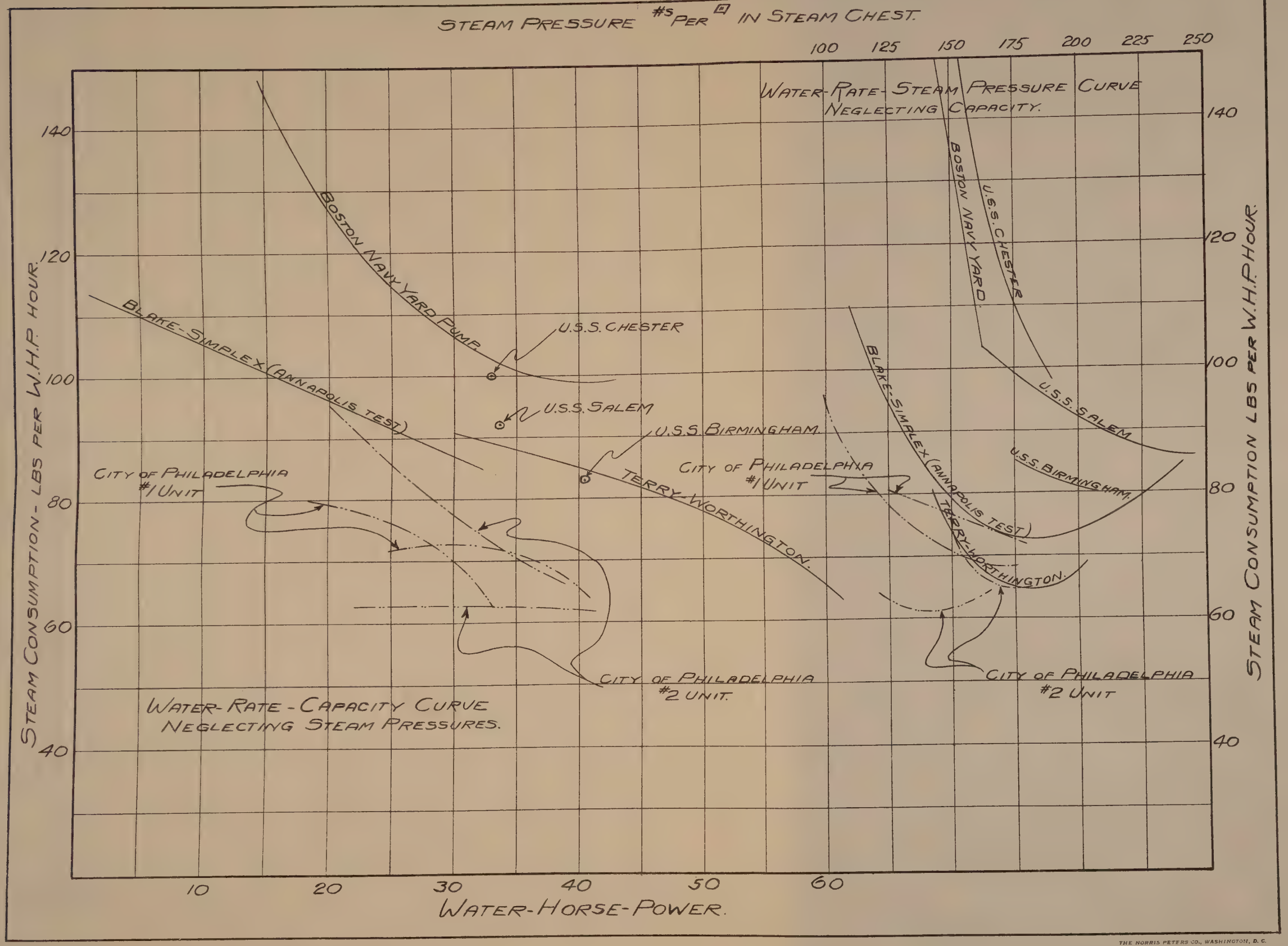

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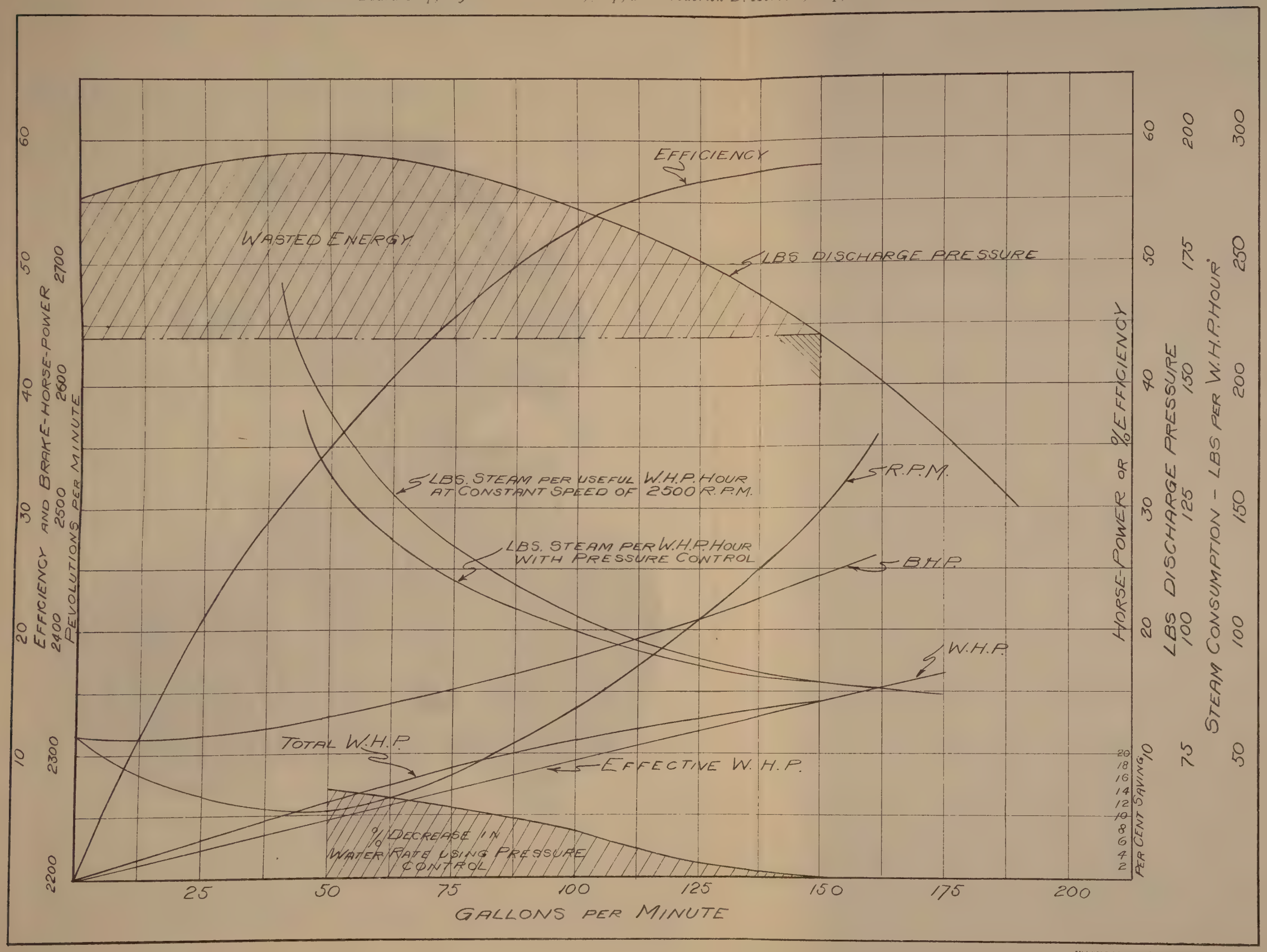
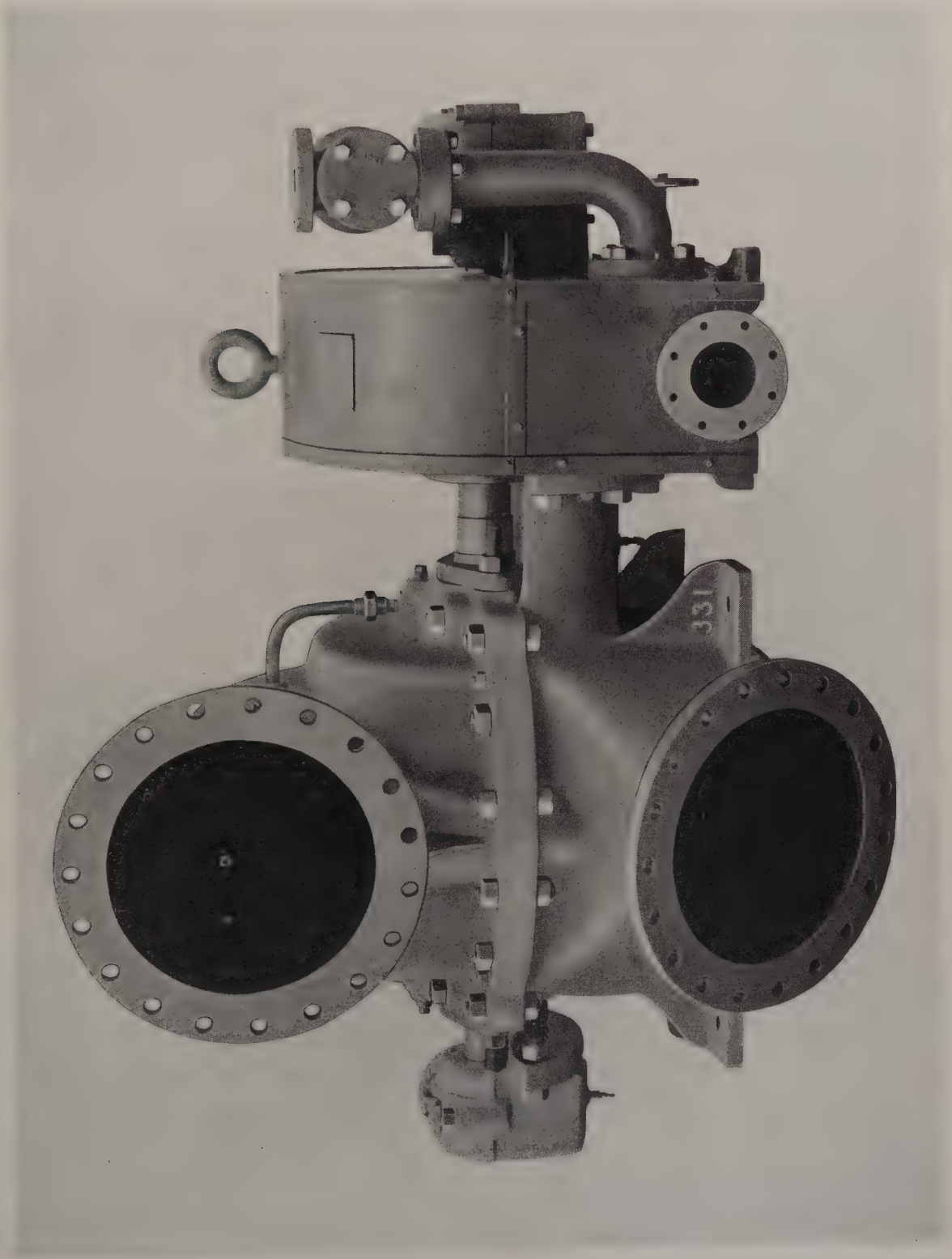
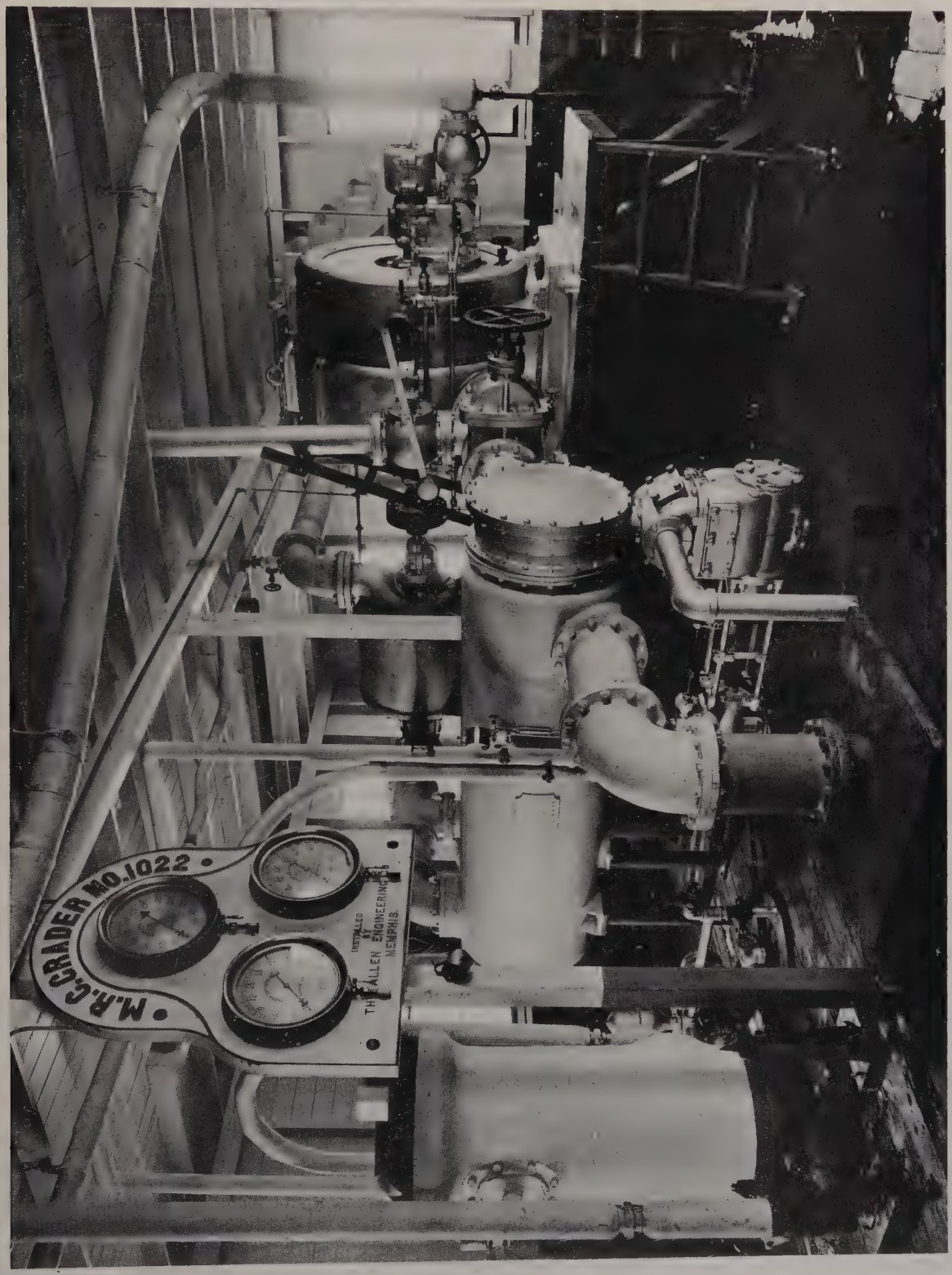


To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



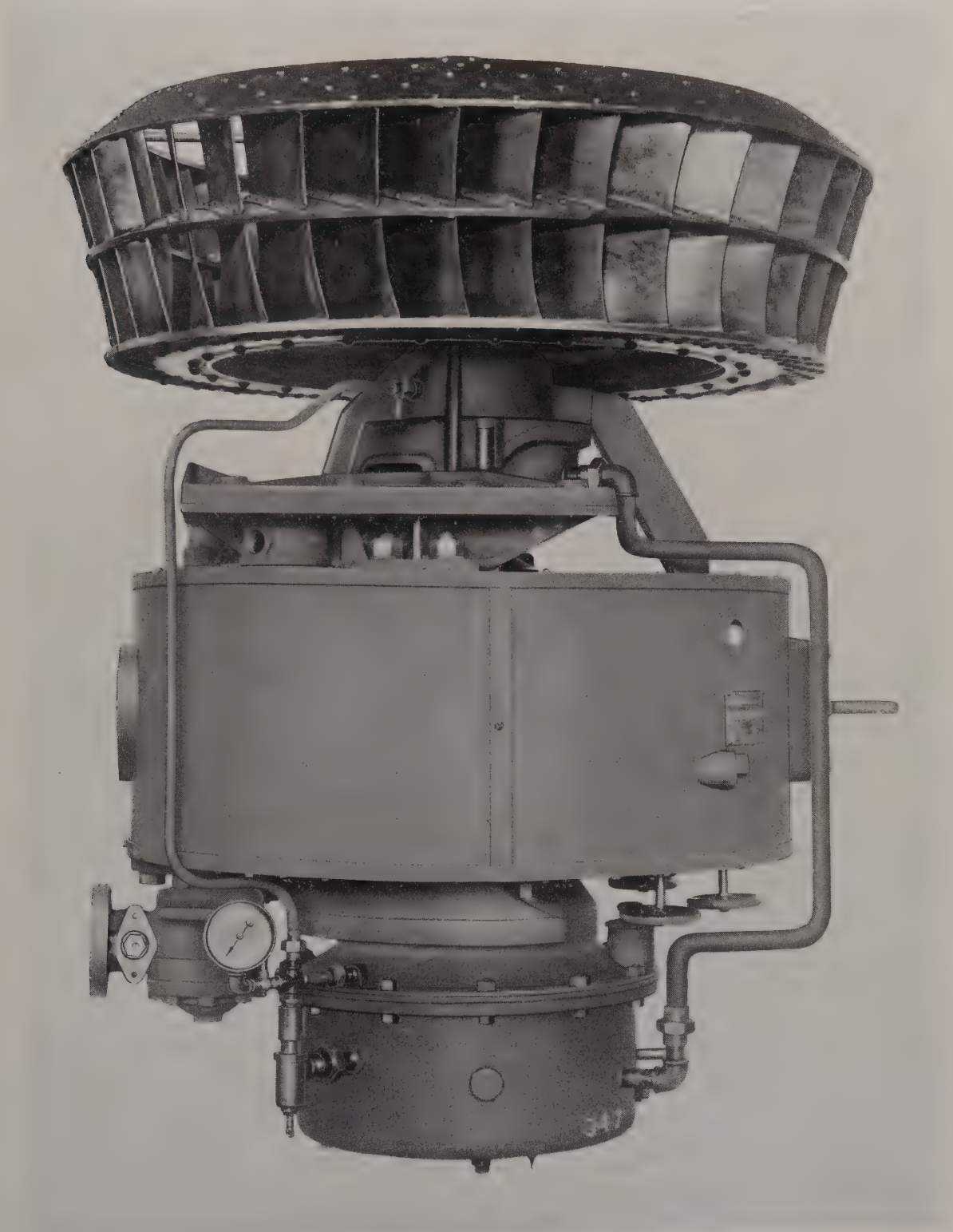
CONDENSING CIRCULATING 3-BEARING TERRY-WORTHINGTON PUMPING UNITS.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



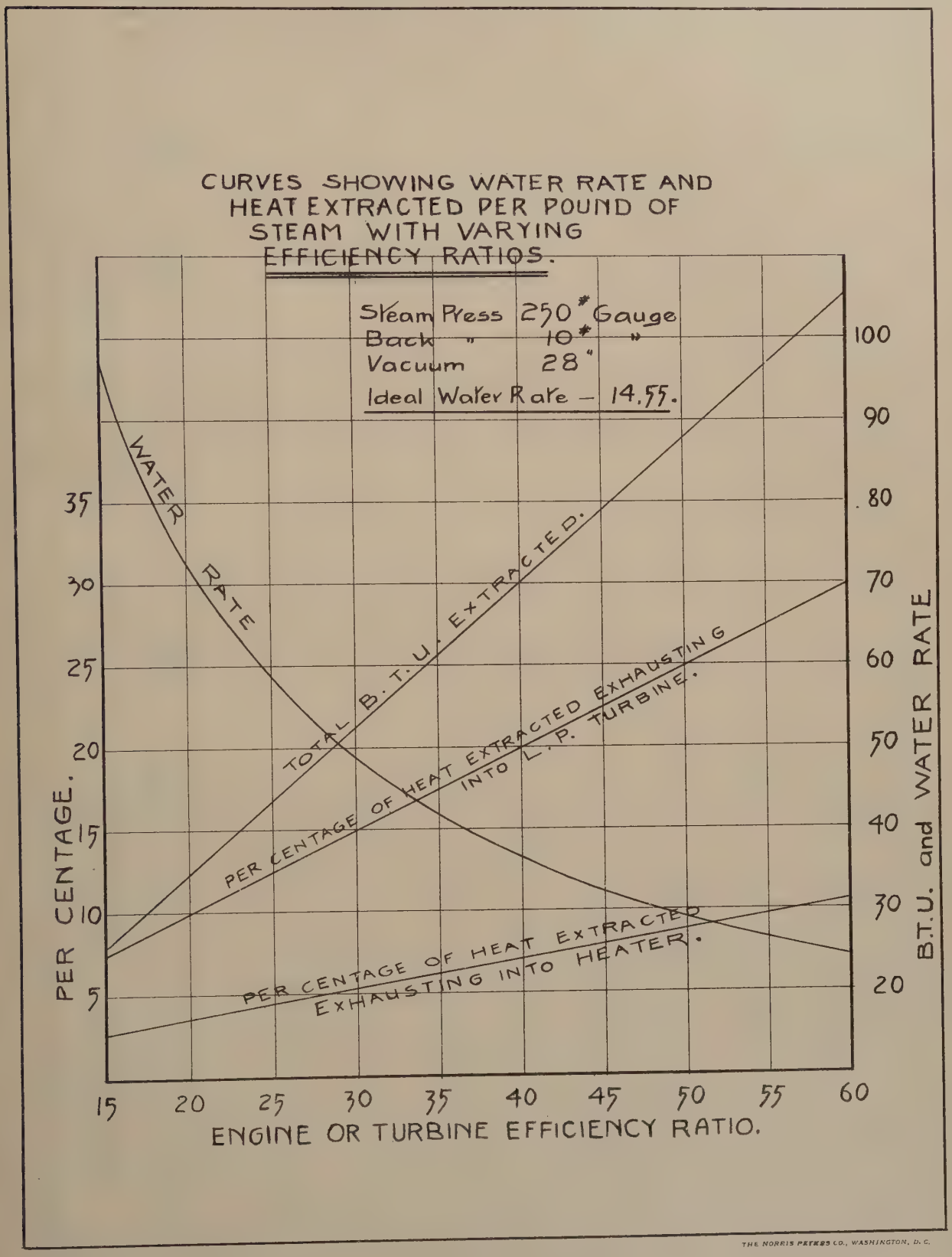
TERRY TURBINE PUMPING SET MOUNTED ON DREDGE FOR USE IN GRADING BANKS OF THE MISSISSIPPI RIVER.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



New Vertical 2-Bearing Terry Forced-Draft Set. 32,000 Cubic Feet Per Minute. 6 Inches Pressure.

To illustrate paper on "The Application of Small Steam Turbines for Auxiliary Purposes on Board Ship," by W. J. A. London, Esq., and Frederick D. Herbert, Esq., Members.



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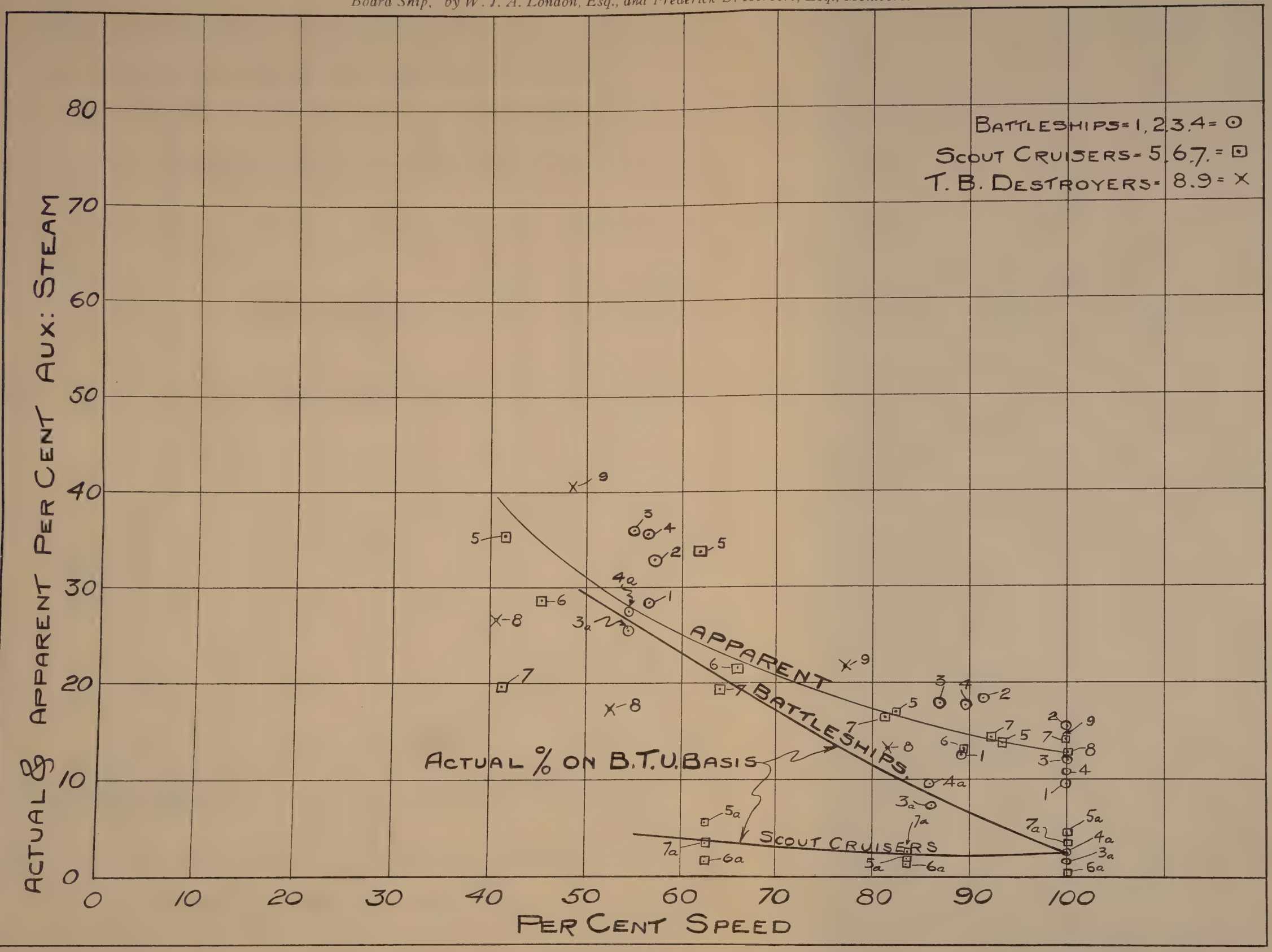

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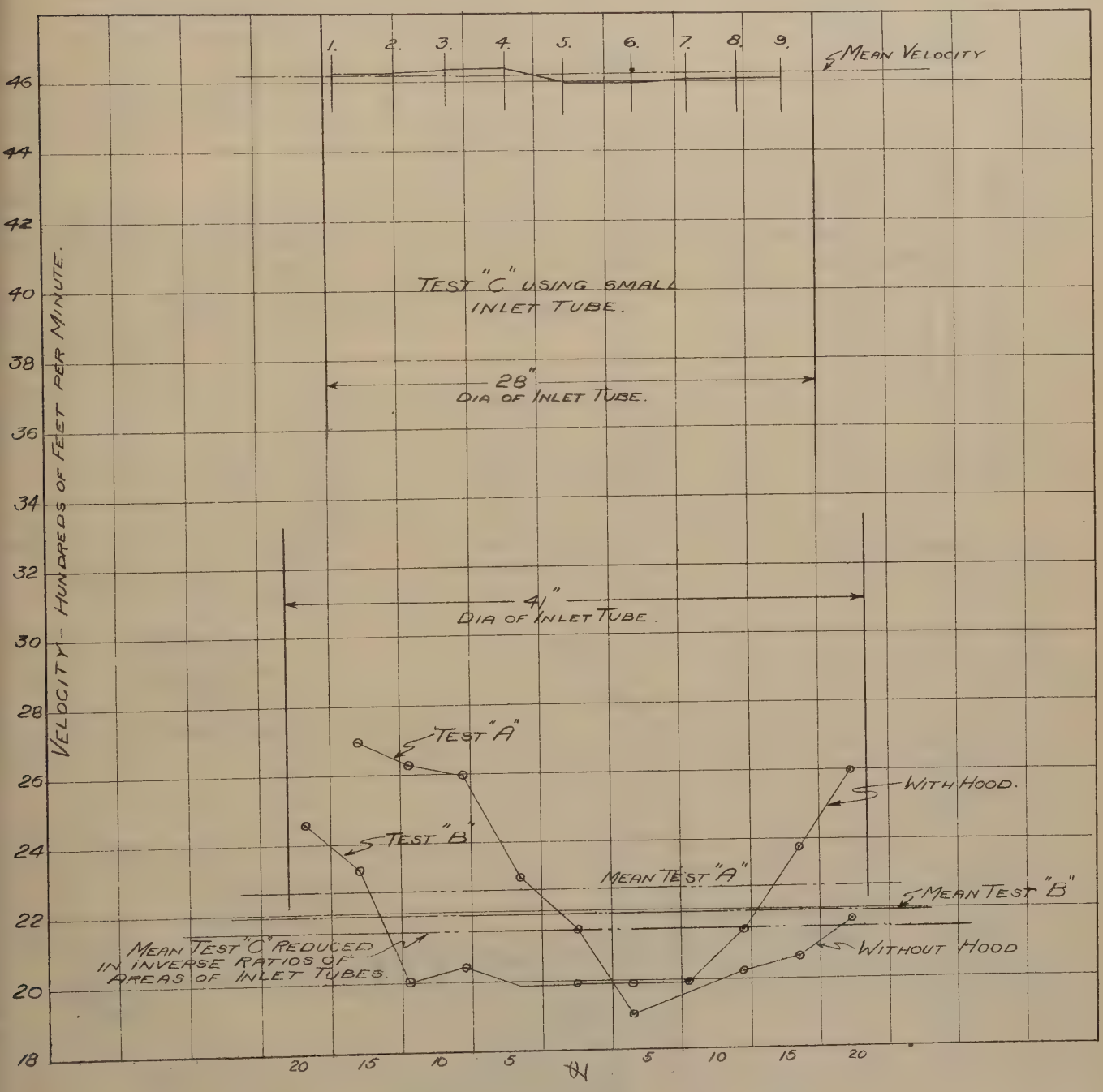

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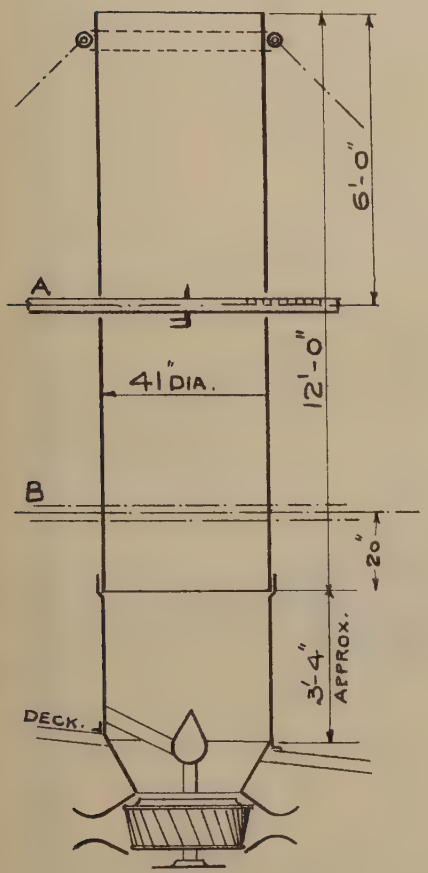
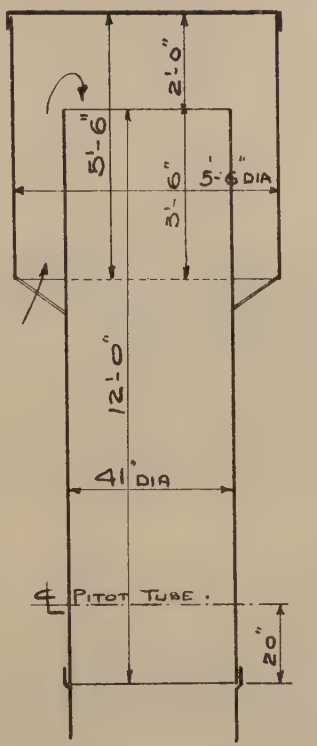
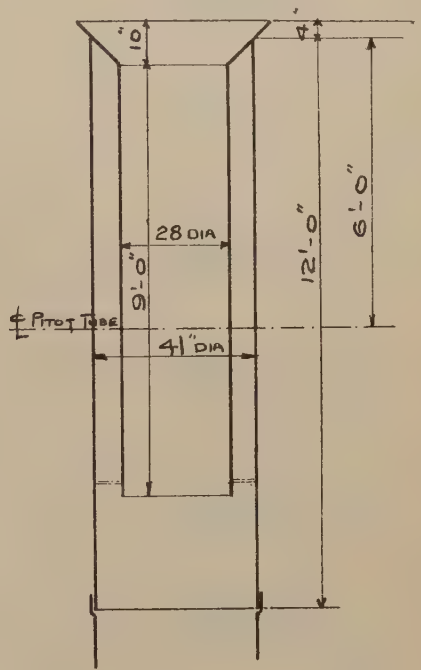


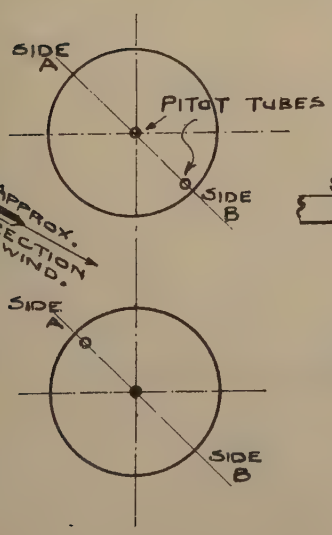
1ST EXPERIMENT.

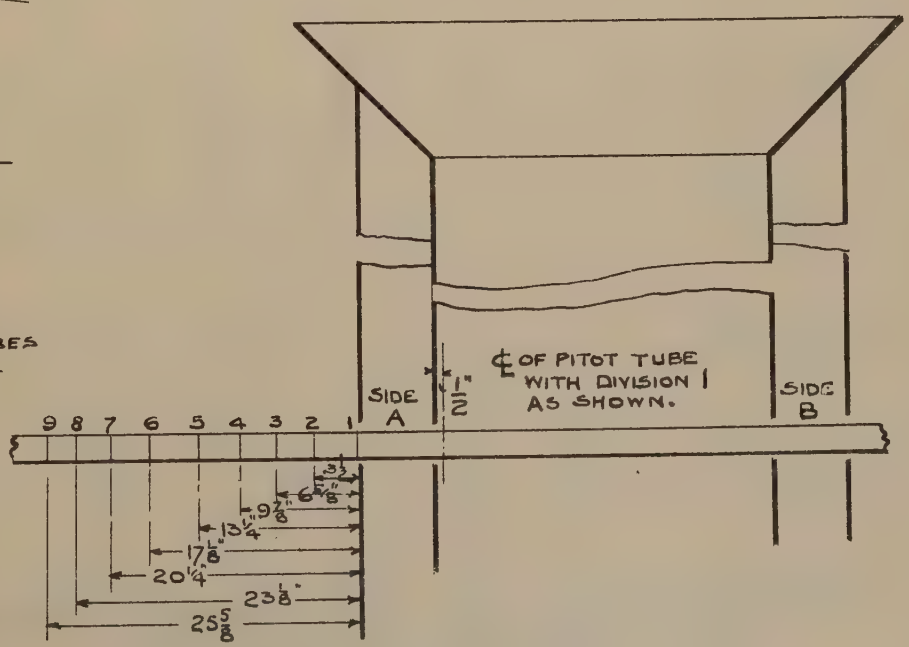


2nd EXPERIMENT



3rd EXPERIMENT.





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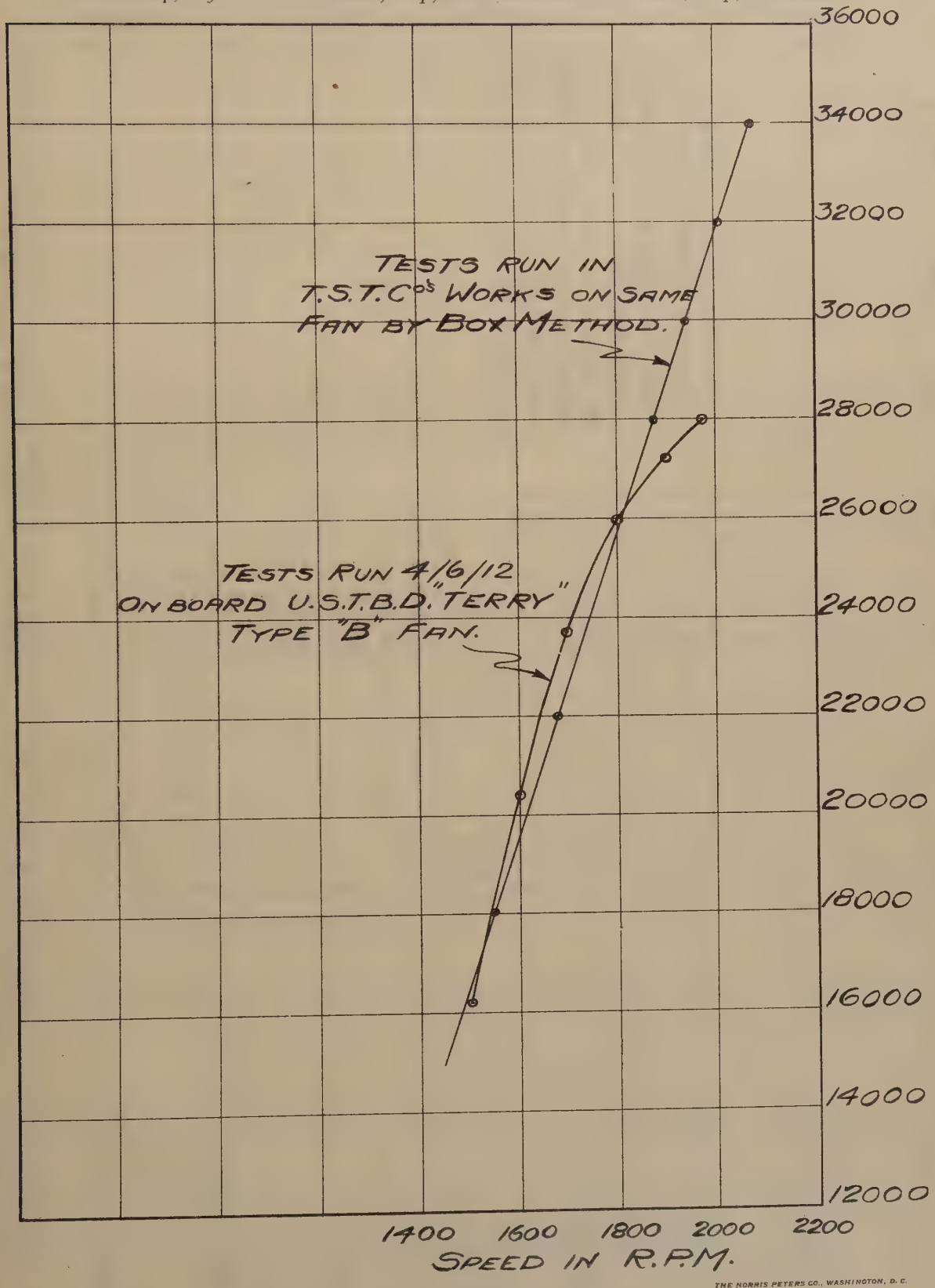

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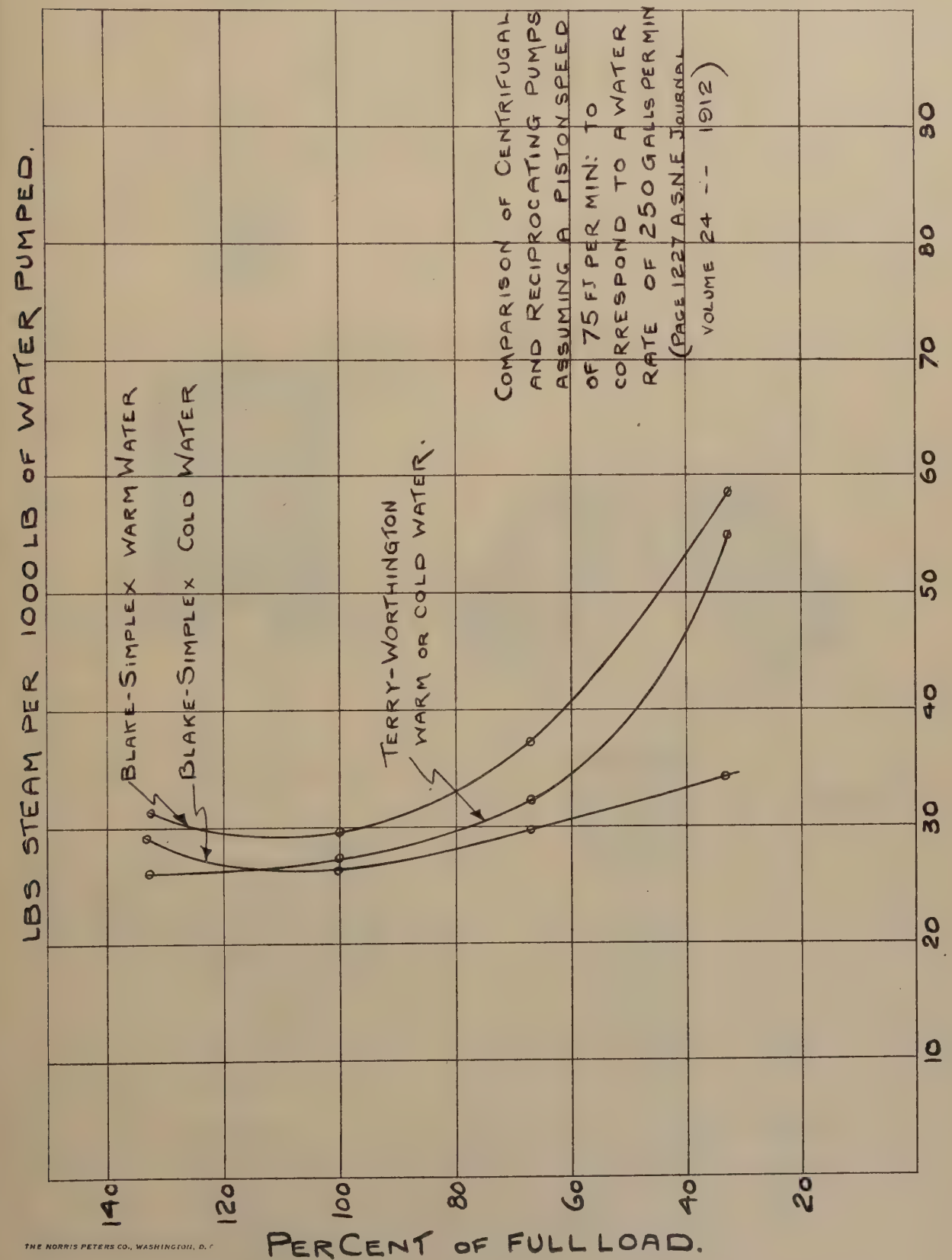

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Superheated Steam in Marine Practice," by Henry B. Oatley. Esq.. Member.

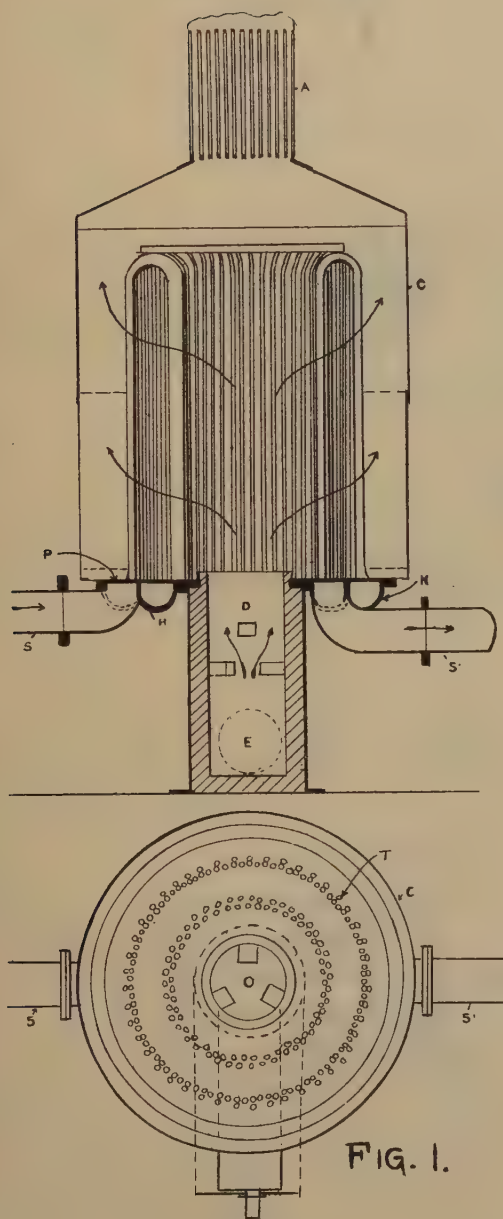

FIG. 1.

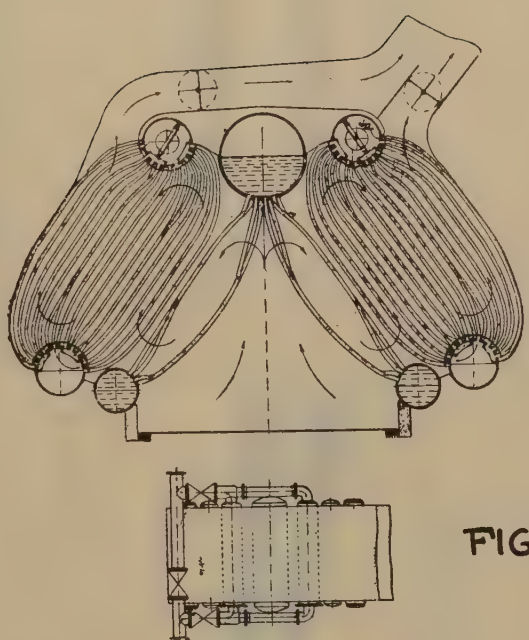

FIG. 2.

WATKINSON

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To illustrate paper on "Superheated Steam in Marine Practice," by Henry B. Oatley, Esq., Member.

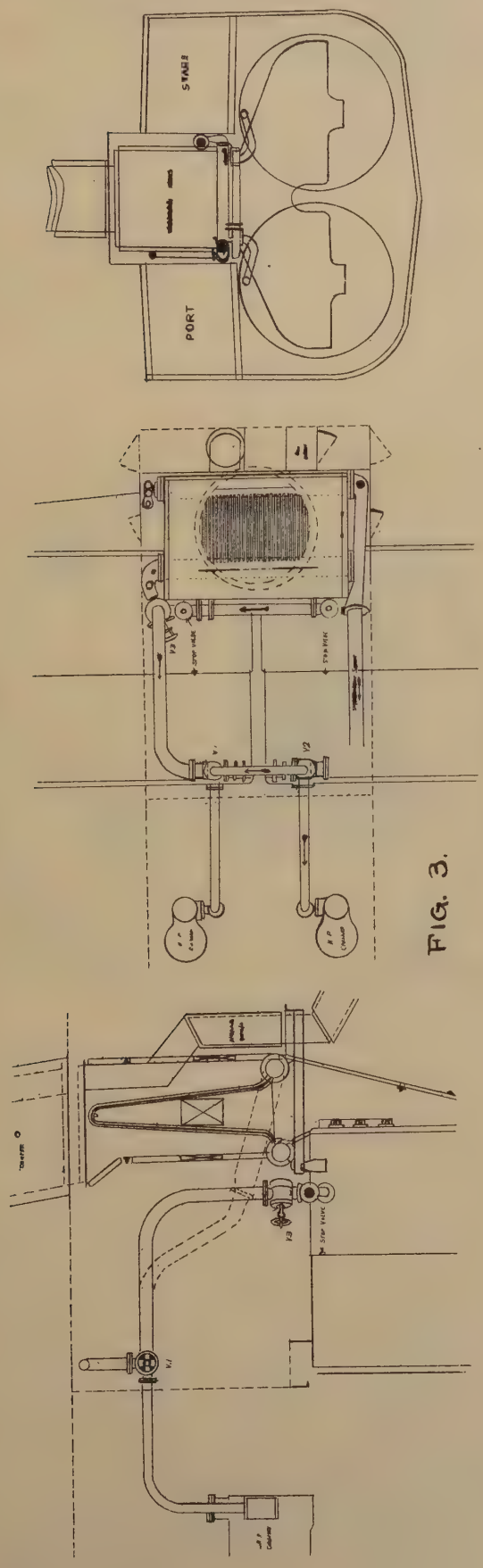

FIG. 3.

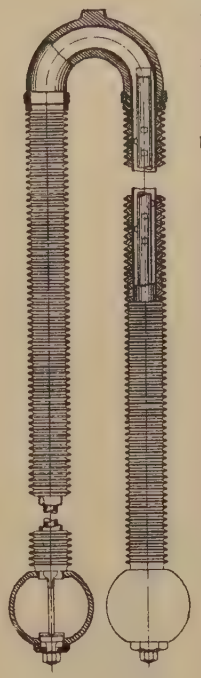

FIG. 5.—CROSS-SECTIONAL VIEW OF RETURN-BEND ELEMENT AND CONNECTING HEADERS USED IN THE CONSTRUCTION OF FOSTER SUPERHEATERS.

FIG. 4.—ONE PROTECTED RETURN ELEMENT OF FOSTER SUPERHEATER, SHOWING INLET AND OUTLET HEADERS.

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Superheated Steam in Marine Practice," by Henry B. Oatley, Esq., Member.

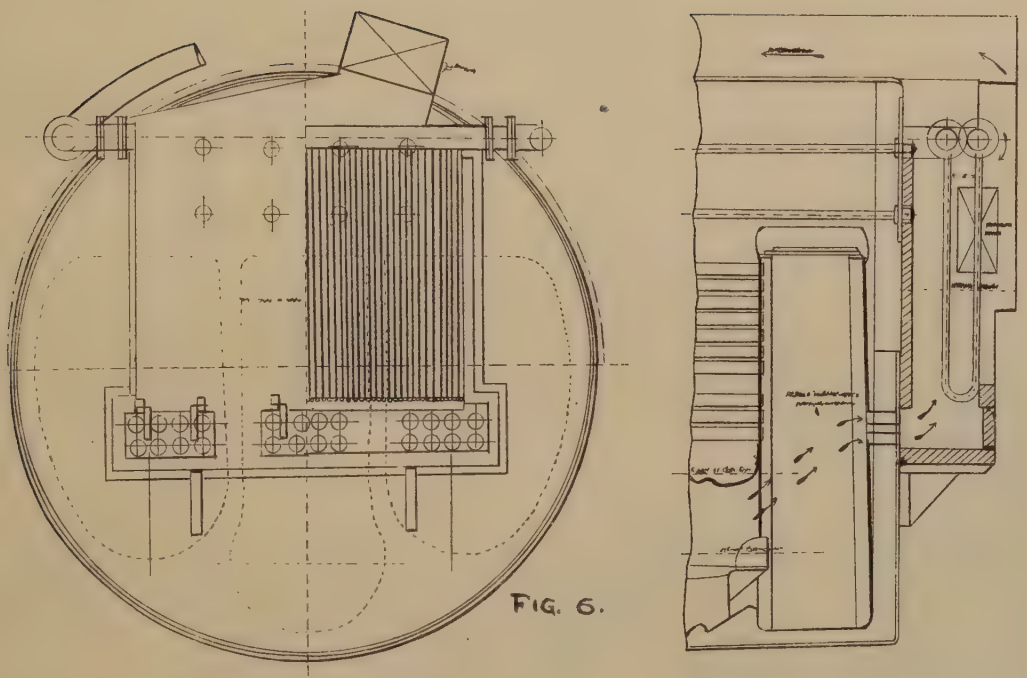

FIG. 6.

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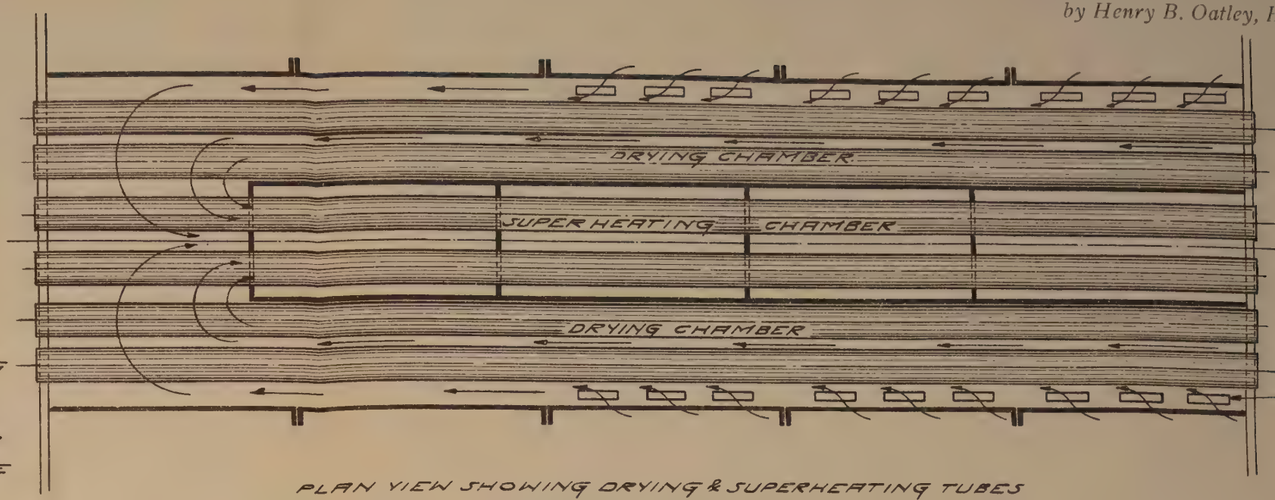
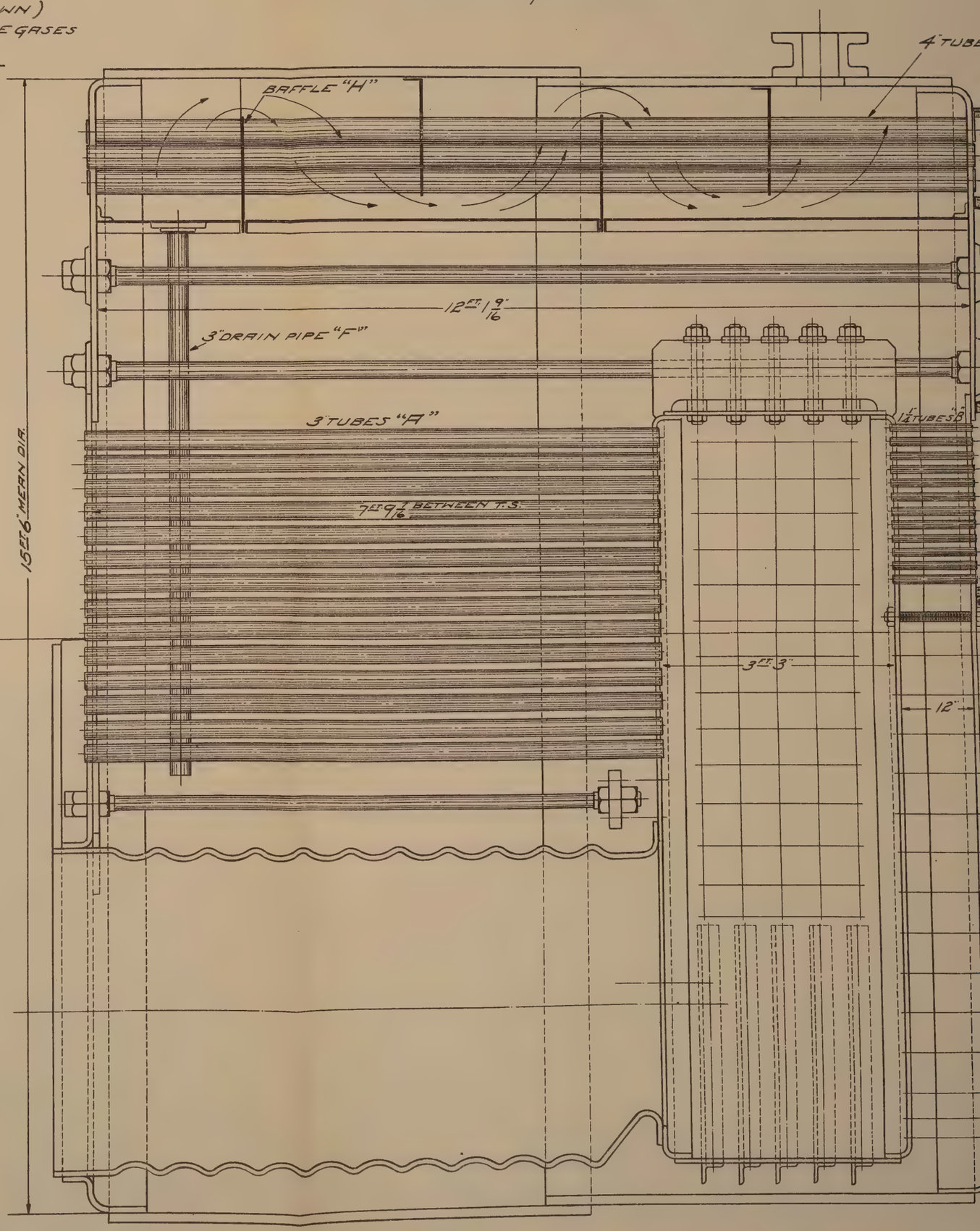
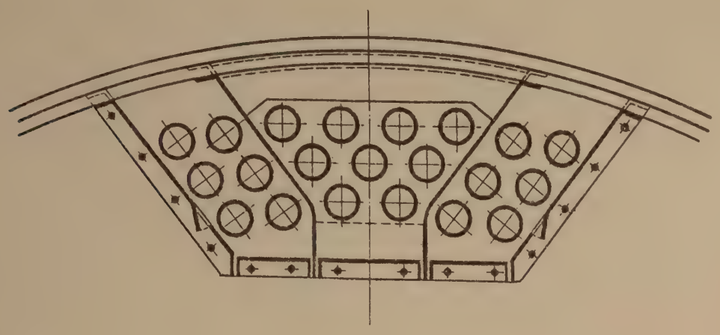
E:-

STEAM ENTERS THROUGH THE VARIOUS SLOTTED
NGS IN THE SIDES OF THE OUTER CASING, PASSES
HE DRYING TUBES WHERE THE GREATER PART OF THE
IRE IS TAKEN OUT OF THE STEAM. ANY WATER REMAINING
ES IN THE CHAMBERS "G"-"G" AND IS DRAINED TO THE
PART OF THE BOILER BY PIPE "F." THE STEAM TRAVELS
HE DRYING TUBES TOWARD THE FRONT OF THE BOILER
IT ENTERS THE SUPERHEATING CHAMBER OVER BAFFLE
E STEAM IS THEN COMPELLED TO PASS IN COUNTER-
NT OVER THE SUPERHEATING TUBES SEVERAL TIMES
O THE ARRANGEMENT OF THE BAFFLES AS SHOWN)
NALLY LEAVES THE BOILER AT A POINT WHERE GASES
HIGHEST TEMPERATURE ARE ENTERING.
L BE NOTED THAT WITH THIS ARRANGEMENT
CAN BE NO POSSIBILITY OF ANY MOISTURE
MAY BE CARRIED ALONG WITH THE STEAM
NT AFFECTING THE FINAL SUPERHEATING
STEAM AS THE MOISTURE IS EITHER ALL
RBED BY THE DRYING TUBES BEFORE IT
S THE FINAL SUPERHEATING CHAMBER,
OLLECTED AND DRAINED OFF.
LATES ARE MADE REMOVABLE IN ORDER TO
CCESS TO THE BOILER FOR EXAMINATION.



PLAN VIEW SHOWING DRYING & SUPERHEATING TUBES
ALSO STEAM INLETS TO DRYING TUBES AND THE BAFFLES
WITHIN THE SUPERHEATING CHAMBER.





IS PRESSED OUT SO AS TO
SLOTS FOR THE ENTERING STEAM.

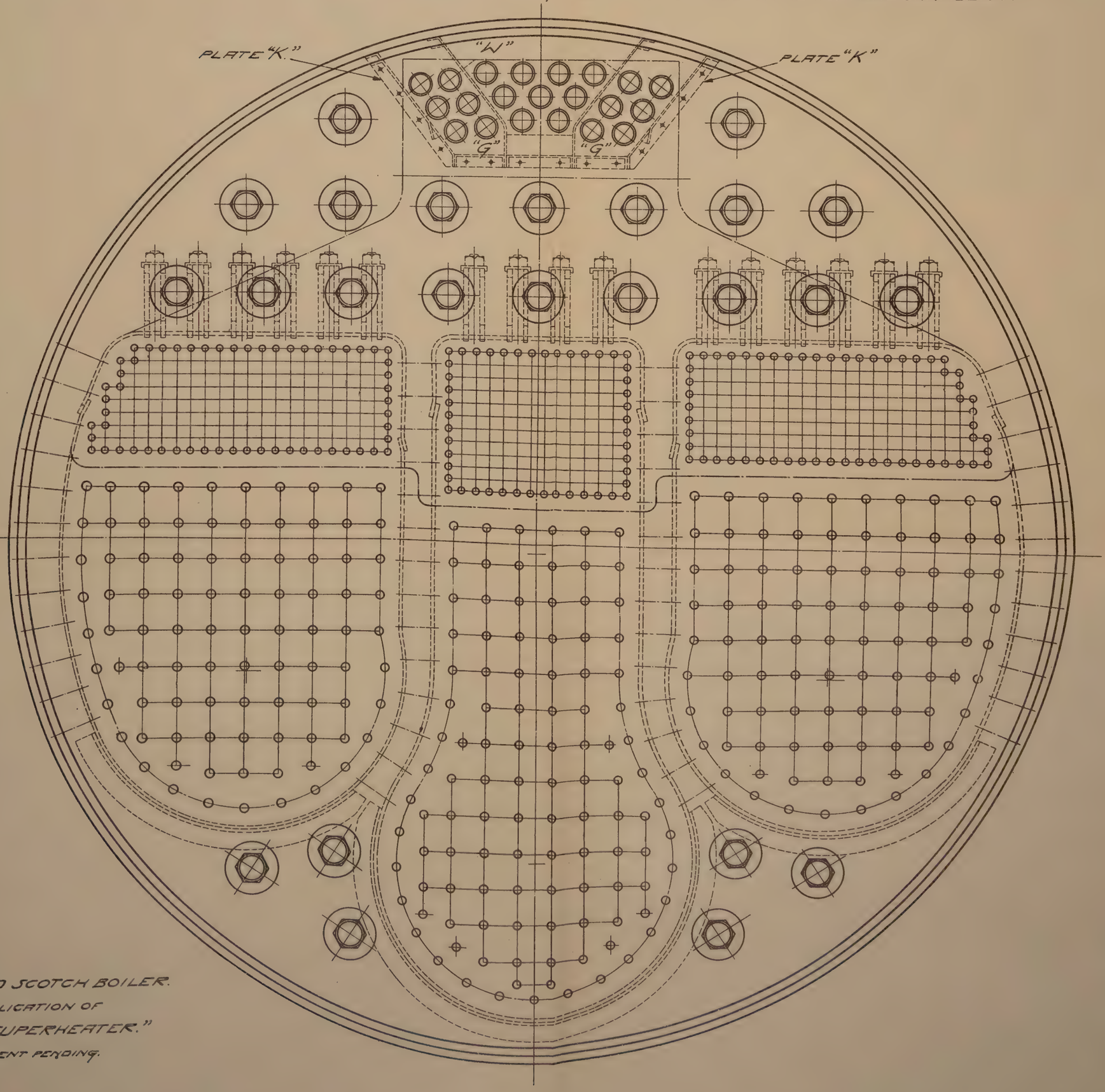
NOTE:-
THE LOCATION OF THE SLOTS FOR THE ENTERING STEAM ARE IN A MOST FAVORABLE POSITION FOR AVOIDING ANY WATER BEING THROWN INTO SAME, WHICH MAY BE CAUSED BY ROLLING OF THE SHIP OR OTHERWISE.

HEATING SURFACE TUBES "A"	1988 SQ.FT.
" " " "B"	178 " "
" " FURNACES	307 " "
" " COMBUSTION CHAMBERS	312 " "
" " BACK TUBE PLATES	84 " "
TOTAL	2869 " "
SUPERHEATING SURFACE- TUBES "C"	266 " "
VOLUME COMBUSTION CHAMBERS	325 CU.FT.
" FURNACES	292 " "
TOTAL VOLUME COMBUSTION SPACE	617 " "
CALORIMETER TUBES-"A"	12.6 SQ.FT.
" " "B"	3.0 " "
" " "C"	1.4 " "

TOTAL H.S. 3135 SQ. FT.

NOTE:-
HEATING SURFACES FIGURED FOR OIL FUEL

DRYING TUBES ARE LOCATED IN THE SIDE CHAMBERS "G"-"G."
SUPERHEATING TUBES ARE LOCATED IN THE CENTRAL CHAMBER "W"



GLE ENDED SCOTCH BOILER.
SHOWING APPLICATION OF
OVEKIN SUPERHEATER."
PATENT PENDING.

To illustrate paper on "Superheated Steam in Marine Practice," by Henry B. Oatley, Esq., Member.

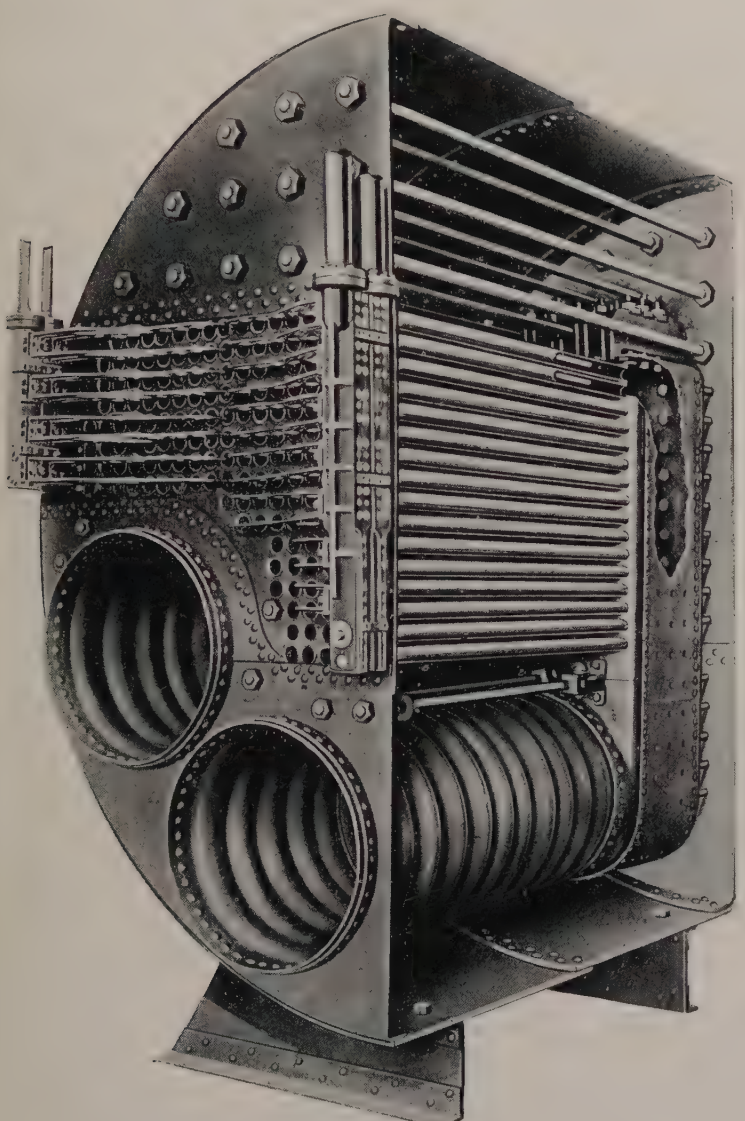


Fig. 8.—Schmidt Fire-Tube Superheater.

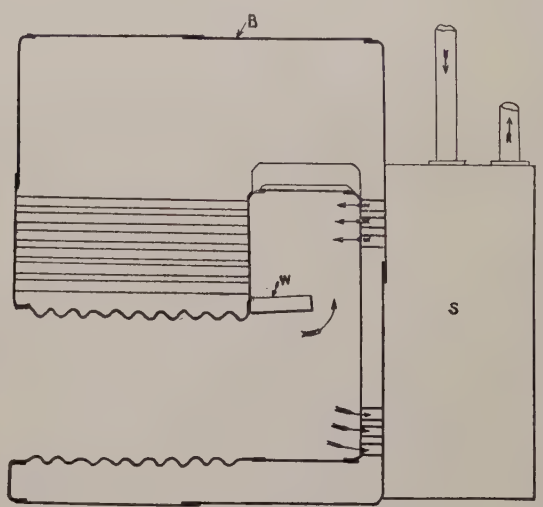


Fig. 9.—Watkinson Superheater.

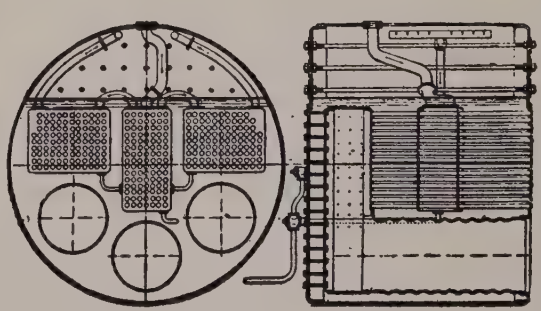


Fig. 10.—The Pielock Superheater.

To illustrate paper on "Superheated Steam in Marine Practice," by Henry B. Oatley, Esq., Member.

SOME RESULTS OF TESTS ON STEAMERS EQUIPPED WITH SUPERHEATERS

Date	S.S.Company	Steamer Name	New or CON	Engs	Draft	I.H.P.	Fuel Economy in %	Fuel Per I.H.P.	S.H. in Fahr. degrees	Steam Economy in %	Steam Per IHP	Type of Blr.	Type of Blr.	St. Pressure	Temp. of St. as used	Remarks	Reference
1857 (?)	Intercolonial Royal Mail Co.	Prince Alfred				200	30-35						Partridge				Mech.Mag. Apr.26,1861
1857		H.M.S. Dee															"
1859		H.M.S. Butler											Parson & Pilgrim				"
1859-1860		Osprey					33 (1)						"		440°		"
about 1860		Damascus				200	3 lbs.saving in coal per 1.H.P.						Partridge				"
"		Tyne				400	very beneficial						"				"
1860		Southampton		simp		262		12 lbs (3)					Boden and Clark				"
before 1861		City of Nantes					30 (2)						Butlin				"
1903		Jas. C. Wallace		quad	nat. Ind.	1559.2	14.2%	1.515	81.7°			B.&W.	B.& W.				Jour.of A.S. N.E.Vol XVII
1909	U.S.Navy	Michigan		trip	for-ced	16016		1.51	85.70			"	"				Inter.Mar.Engrg July 1912
"	" " "	So.Carolina		"	"	17651		1.395	47,5			"	"				"
"	Idealia			"					57 88 96 105	7.1% 13.66 13.66 15.30	17.0 15.8 15.8 15.5	"	"				"
"	Oldenburg-Portugies D.Reed., Oldenburg	12 diff. ships	con	"	nat.	500-1000	15%					Scotch	Schmidt				owners
1910	Sou.Pacific Co.	Creole		"		7000	16.38 to 17.45					B.&W.	B.& W.				International Mar.Engrg. July 1912
1910	Moss Werft Moss in Norwegen	Trygve	con	comp	nat.		25%					Scotch	Schmidt				Owners
"	Det Forenede Damps.Selskab Kopenhagen	"Odin" & "Ydun"	new	trip	"	900	15.5	1.33				"	"				"
"	Cie Generale Transatlantique Paris	La Garonne	con	"	Howd.	1300	15%	1.27				"	"		Av. of 8 voy.dur.8 mos. ser.		"
"	Chargeurs Reunis Le Havre	Admiral Jaureguiberry	"	"	nat.	2200	14.5%	1.31				"	"				"
1911	Milburn & Co.	Port Augusta	"	"	Howd.	2005	12.8-15%	1.454				"	"	180			Inst.of Nav. Arch.Apr.2,1914
"	" " "	Port Lincoln	new	quad	"	4027	12.0%	1.29	211°			"	"	220	600°		"
1912	MacAndrew & Co	Pelayo	con	trip	nat.	750	19%	1.32				"	"	165			owners
"	" " " "	Cid	"	"	"	750	18%	1.32				"	"	165			"
"	Dampfschiff-Ges.Kawkus u. Merkur,St.Pet.	Olga Mikolajewna	"	comp	"	1100	23%	1.29				"	"				"
1913	Hamburg-Amer. Linie,Hamburg	Kurmark	new	trip	Howd.	2100		1.256				"	"				"
"	Lancanshire Shpg.Co.Ltd. J.Chambers & Co.	BOlton Castle	"	"	nat.	2700	15.5%	1.26				"	"	180	comparison is with sister ship		"
"	Lamport & Holt	Dryden	"	"	"	2600	13.5%	1.31				"	"	180	comp. in % is with sister ship		"
"	Argo Dampf. Ges. Bremen	Möve	"	"	Howd.	1600		1.10				"	"				
1914	Lowden & Co.	Ferrona	"	"	nat.	1925		1.15 1.20	200°			"	"	180	580°	So.Wales Coal Amer. Coal	Fairplay(Lon.) Sept.2, 1915
1915	Bucknall S.S. Co.	Kandahar	"	"	Howd.	3100	13.0%	1.25				"	"	220			Fairplay (Lon.) Nov.18, 1915
"	Stoomvart Maatschappij (Amsterdam)	Nederland	"	"	"	4200	13.0%	1.27				"	"	180			"
"	Booth Lines	Stephen	"	"	"	2000	14%	1.29				"	"	180			"
"	Otto Thoresen (Christiania)	San Jose	"	"	"	1500	14.0%	1.34				"	"				"
1915	Anglo-Saxon Pet. Co. (London)	Melania	new	trip	Howd.	2400	15.0%	1.32				"	"	180			"
"	Nippon Yusen Kaisha	Yasaka Maru	"	"	"	4000	14.0%	1.25				"	"	200			"
"	MacAndrew & Co	Valdes	"	"	"	1250	15.5%	1.29				"	"	180			"

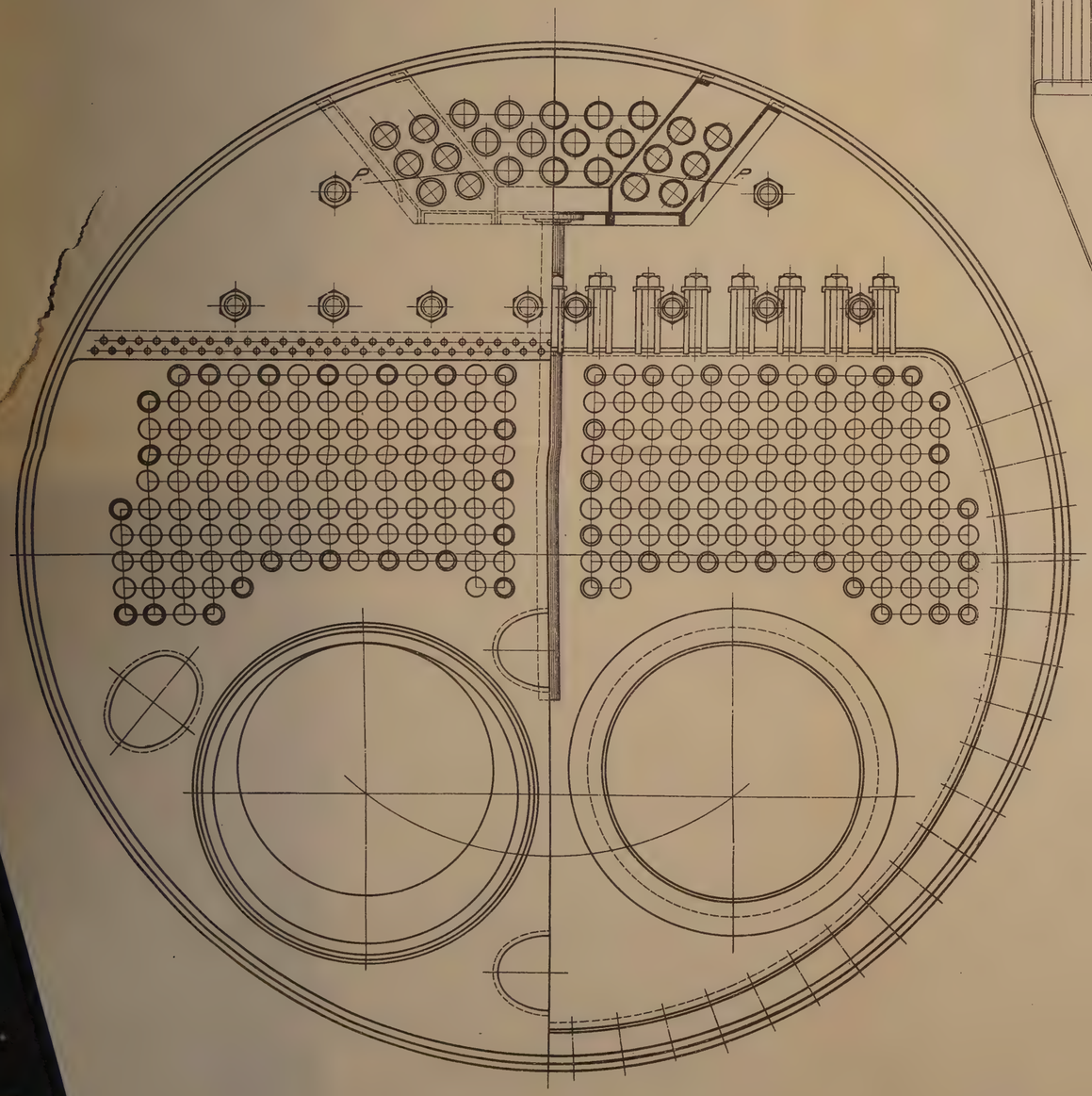
(1) gain of 11% in R.P.M. and lower boiler pressure
(2) gives added speed
(3) this is based on N.H.P.

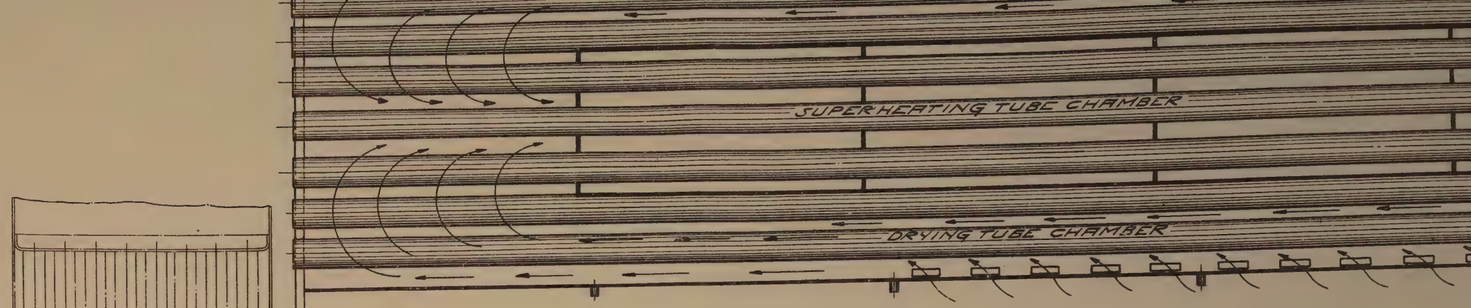
NOTE:-

STEAM ENTERS THROUGH THE VARIOUS SLOTTED OPENINGS IN THE SIDES OF THE OUTER CASING, PASSES OVER THE DRYING TUBES WHERE THE GREATER PART OF THE MOISTURE IS TAKEN OUT OF THE STEAM. ANY WATER REMAINING SETTLES IN THE CHAMBERS "G"-"G." AND IS DRAINED TO THE LOWER PART OF THE BOILER BY PIPE "F." THE STEAM TRAVELS OVER THE DRYING TUBES TOWARD THE FRONT OF THE BOILER WHERE IT ENTERS THE SUPERHEATING CHAMBER OVER BAFFLE "H." THE STEAM IS THEN COMPELLED TO PASS IN COUNTER-CURRENT OVER THE SUPERHEATING TUBES SEVERAL TIMES (DUE TO THE ARRANGEMENT OF BAFFLES AS SHOWN) AND FINALLY LEAVES THE BOILER AT A POINT WHERE GASES OF THE HIGHEST TEMPERATURE ARE ENTERING.

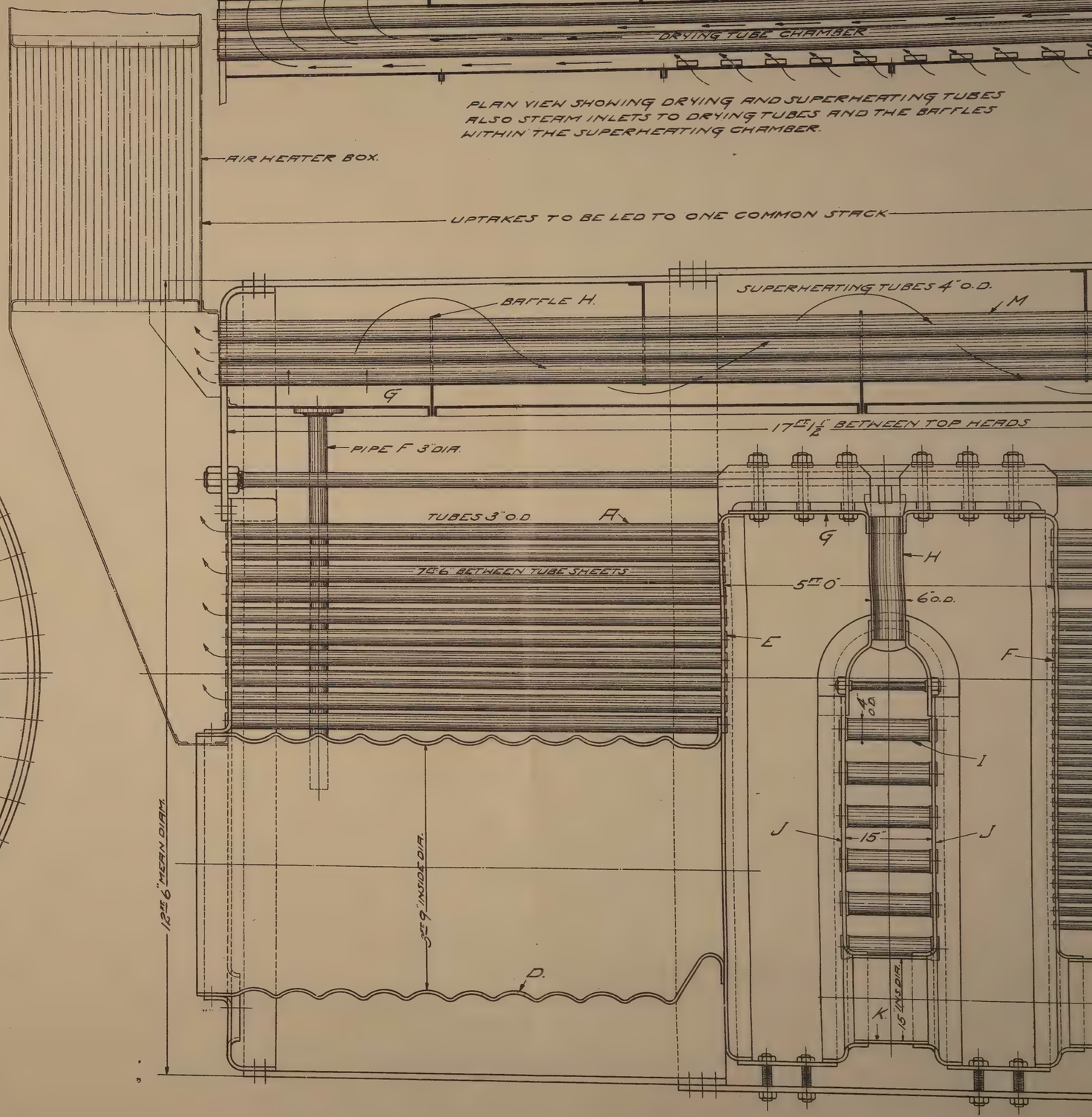
IT WILL BE NOTED THAT WITH THIS ARRANGEMENT THERE CAN BE NO POSSIBILITY OF ANY MOISTURE WHICH MAY BE CARRIED ALONG WITH THE STEAM CURRENT AFFECTING THE FINAL SUPERHEATING OF THE STEAM, AS THE MOISTURE IS EITHER ALL ABSORBED BY THE DRYING TUBES BEFORE IT ENTERS THE FINAL SUPERHEATING CHAMBER, OR IS COLLECTED AND DRAINED OFF.

ALL PLATES ARE MADE REMOVABLE IN ORDER TO GIVE ACCESS TO THE BOILER FOR EXAMINATION.



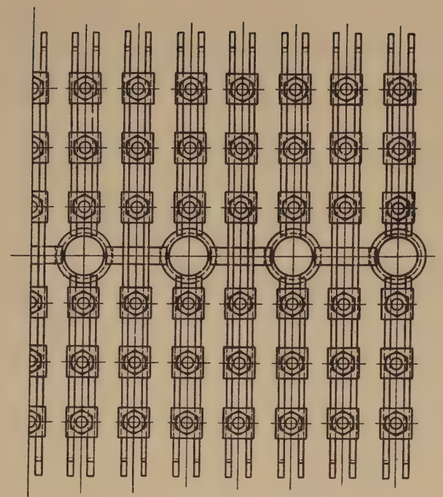


PLAN VIEW SHOWING DRYING AND SUPERHEATING TUBES ALSO STEAM INLETS TO DRYING TUBES AND THE BAFFLES WITHIN THE SUPERHEATING CHAMBER.

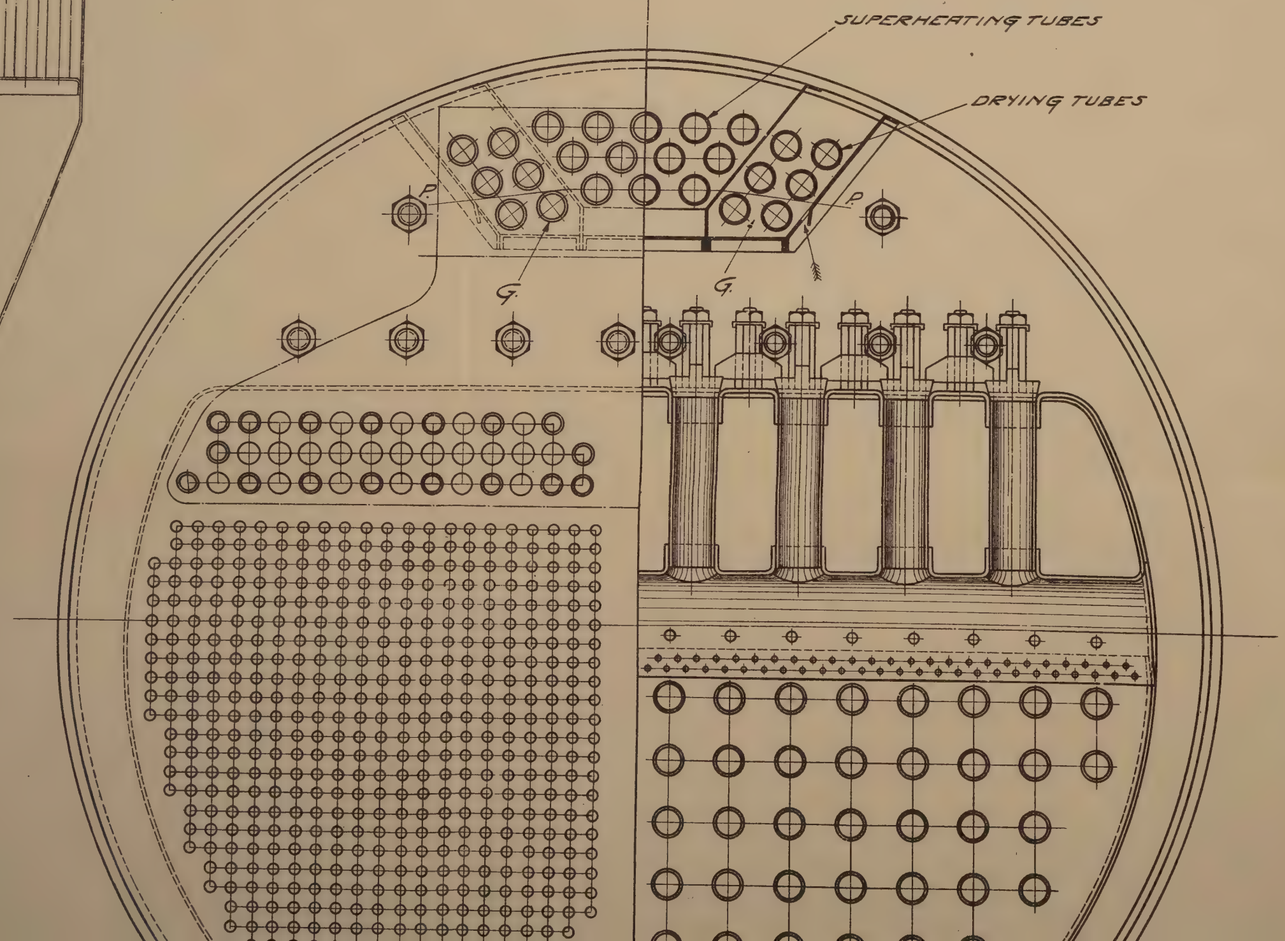


entitled
, Member.

PLATE IS PRESSED OUT SO AS TO FORM SLOTS FOR THE ENTERING STEAM.
NOTE:- THE LOCATION OF THE SLOTS FOR THE ENTERING STEAM ARE IN A MOST FAVORABLE POSITION FOR AVOIDING ANY WATER BEING THROWN INTO SAME, WHICH MAY BE CAUSED BY ROLLING OF THE SHIP OR OTHERWISE.
IR HEATER BOX



PLAIN VIEW OF GIRDERS.



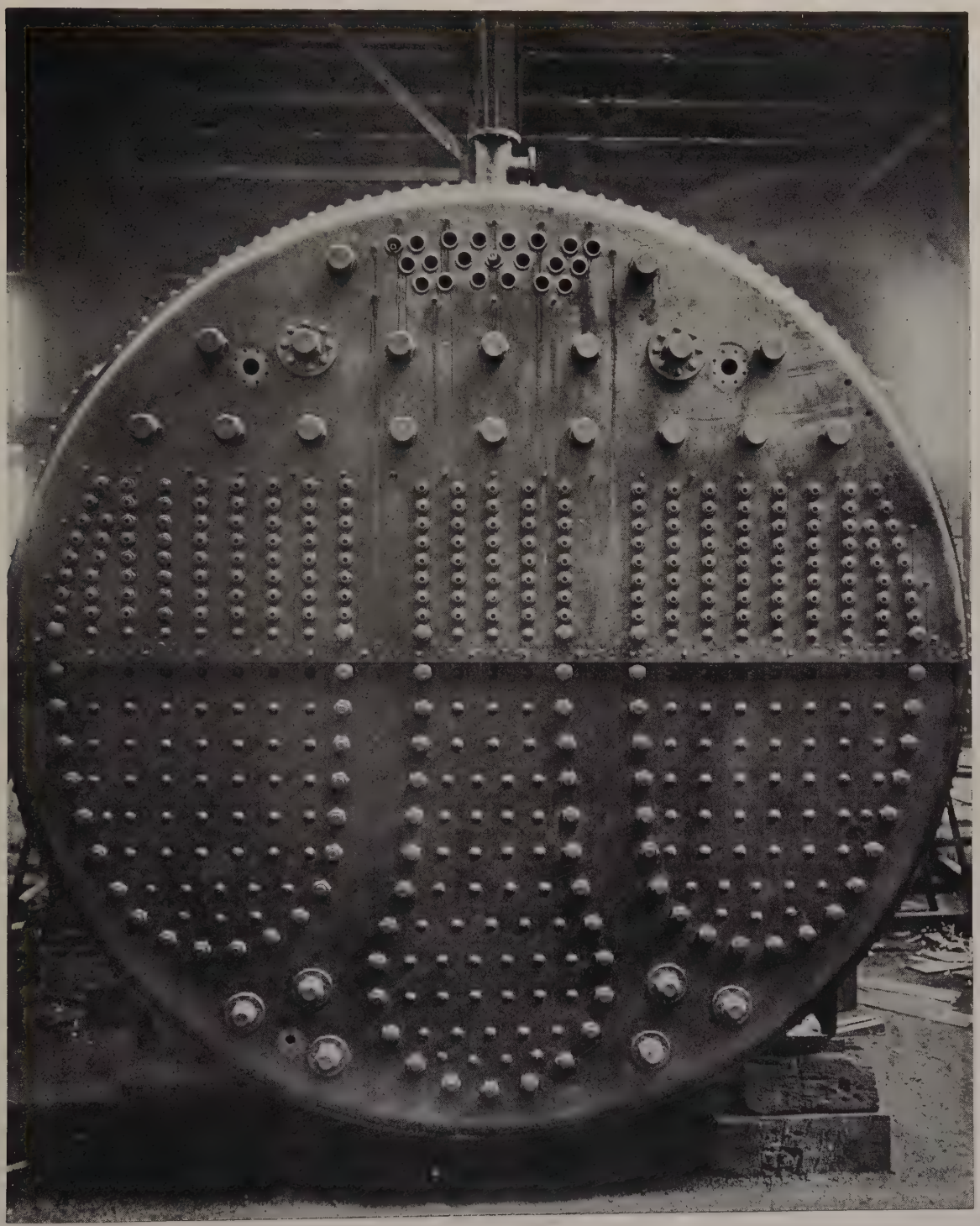
HEATING SURFACE		
TUBES	1378 SQ.FT.	A
TUBES	275 " "	B
TUBES	1714 " "	C
FURNACES	212 " "	D
BACK TUBE PLATE.	41 " "	E
BACK TUBE PLATE	51.5 " "	F
WRAPPER PLATE	133 " "	G
COMB. CHAMB. TUBES	25 " "	H
COMB. CHAMB. TUBES	104.7 " "	I
COMB. CHAMB. DIVISION	107.3 " "	J
COMB. CHAMB. FLUE	5.2 " "	K
FLUE	18.8 " "	L
TOTAL HEATING SURFACE	4065.5 " "	
VOLUME OF FURNACES	184.5 CU.FT.	TOTAL
VOLUME OF COMB. CHAMB.	296. " "	480½
CALORIMETER	9.05 SQ.FT.	A
CALORIMETER	2.98 " "	B
CALORIMETER	8.25 " "	C
STEAM VOLUME	329. CU.FT.	
SUPERHEATED SURFACES	430.2 SQ.FT.	M
CALORIMETER	1.6 " "	M

LOVEKIN PATENT BOILER
ESPECIALLY DESIGNED FOR BURNING FUEL OIL.

DIAM-	12FT 6"
LENGTH- INSIDE	17FT 0"
WORK. PRESS.-	200# GAUGE
HEATING SURFACE	4065 SQ. FT.
SUPERHEATING SURFACE	430 " "
VOLUME COMB. CHAMBER	296 CU. FT.
" FURNACES	184.5 " "
" TOTAL COMBUSTION SPACE	480.5 " "
CALORIMETER- 3" TUBES- FRONT	9.05 SQ. FT.
" 3" " BACK	2.98 " "
" 1½" " "	8.25 " "
" 4" SUPERHEAT. TUBES	1.60 " "
VOLUME OF STEAM SPACE	329 CU. FT.
LIBERATING AREA	187 SQ. FT.
WEIGHT- DRY WITHOUT SUPERHEATER	116,000
" " WITH " "	
" OF WATER AT 200# PRESS.	60,000
EVAPORATION- TOTAL WATER PER HR. FROM AND AT 212°	30,000 LBS.
" WATER PER # H.S.	7.38 "
" WATER PER LB. OIL FROM AND AT 212°	15
OIL BURNED TOTAL PER HOUR	2000 LBS.
" " PER HR. PER # H.S.	.492
" " " " CU.FT. COMB. SPACE	4.16
NO. OF FURNACES	2

HEATED FORCED DRAFT- 5" AIR PRESS.
SPIRAL RETARDERS FITTED

To illustrate discussion by Luther D. Lovekin, Esq., on paper entitled "Superheated Steam in Marine Practice," by Henry B. Oatley, Esq., Member.



THE LOVEKIN SUPERHEATER (UPTAKE REMOVED) AS APPLIED TO A SCOTCH BOILER.

To illustrate discussion by Luther D. Lovekin, Esq., on paper entitled "Superheated Steam in Marine Practice," by Henry B. Oatley, Esq., Member.

THE LOVEKIN SUPERHEATER (UPTAKES OVER SUPERHEATING TUBES).

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